Rapid maxillary expansion in contemporary orthodontic literature

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Abstract

We have reviewed our retrospective research about rapid maxillary expansion performed in the early mixed dentition to summarize the results of different studies regarding maxillary dental arch width variation and crowding improvement in light of contemporary literature. The aim is to define the effects of treatments followed until the end of dental arch growth. In all studies, a Haas expander anchored to the deciduous dentition was used. The samples consisted of treated patients with and without a lateral crossbite and homogeneous untreated individuals as controls. Two additional control groups of adolescents and adults in dental Class 1 were also compared. As a result of the analysis, rapid maxillary expansion with anchorage to the deciduous dentition was found to be effective in increasing transverse width in intermolar and intercanine areas, and the change was preserved until the full permanent dentition stage. When performed before maxillary lateral incisors have fully erupted, this procedure allows for a rapid increase in the arch length in the anterior area and consequently, in the space available for permanent incisors with a stable reduction in crowding over time.

Key words: Anchorage, anterior crowding, arch dimension, cross-bite, rapid maxillary expansion

INTRODUCTION

The rapid maxillary expansion is a procedure used for midpalatal suture opening by means of fixed orthodontic appliances, during growth. The aim is to increase the transverse width of the maxillary arch as the result of dental and skeletal expansion.

The bibliography on this topic is extensive, with the first report by Angell.[1] Over the years, many papers have been published, especially after 1961, when Haas[2] described his expander design and appliance effects.

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Clinical indications for rapid maxillary expansion are a lateral crossbite or a constricted maxillary arch. In addition, the increase in arch length allows for reducing the lack of space for crowded teeth.

Over the years, we have retrospectively analyzed the effects of a Haas expander anchored to the deciduous dentition to improve a lateral crossbite and anterior crowding.[3-7] Some evidence has already been reported about the effectiveness of this anchorage design in the correction of transverse discrepancy.[8]

The uniqueness of this procedure lies in the appliance anchorage. The traditional rapid maxillary expander (Hyrax or Haas) anchors to first permanent molars and bicuspids. The replacement of permanent with deciduous

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dentition as anchorage aims to reduce the risk of negative side-effects on permanent teeth produced by the expansion force[9-14] and/or by plaque accumulation around bands.[15]

In this paper, we review our research about rapid maxillary expansion performed in the early mixed dentition to describe and summarize the effect of early treatment with a Haas expander anchored to deciduous dentition on maxillary dental arch dimensions and anterior crowding and to evaluate its long-term stability until adolescence.

SUTURE STRAIN TIMING AND RESPONSE TO RAPID MAXILLARY EXPANSION

Midpalatal sutures can be orthodontically opened during the period of skeletal growth, before the contact among the maxilla, the palatine bone, and the pterygoid process has become close. More specifically, Melsen and Melsen[16] described changes in the tightness of surface junctions in four stages infantile, juvenile, adolescent, and adult. The older the individual, the more interdigitated the suture and the more difficult its reopening. In particular, fractures were always present on disarticulated bones from dry skulls of adolescents, and suture separation was impossible in adulthood.

For disarticulation of the midpalatal suture with a rapid maxillary expander, a force of 4–9 kg is utilized. The screw is activated daily, and the force is transmitted from the screw across the anchoring anatomical structures (teeth and in the case of the Haas design, the palatal vault) to palatal bones and the cranial base. The suture opens when the load produced by the screw exceeds the resistance of the facial skeleton.[9] However, the decrease in load does not follow a linear trend. From 30% to 50% of the load dissipates within the first 15 min and the last 50–70% over a 24-h period. After this interval, the persistence of a residual load is classified as an increase in skeletal resistance.

Maxillary suture opening is not parallel in the anterior and occlusal views.[17] In the anterior plane, it is triangular, with the vertex at the level of the frontomaxillary suture and the base in the alveolar bone. On each side, the zygomatic arch provides resistance and prevents parallel displacement of the two maxillary halves.

In the palatal view, the opening is also triangular with a greater gain in width in the anterior than in the molar area at a ratio of 3:2.[8] Resistance in the posterior area is produced by the pterygoid process,[17] which is already heavily interdigitated with the maxilla[16] in late childhood. For rigidity, especially, in the area close to the cranial base, the pterygoid plates bend only laterally during expansion.[18]

Holberg and Rudzki-Janson[19] studied stresses occurring in cranial bones (sphenoid, frontal, occipital, and temporal bones), particularly near the foramina, when the pterygoid process bends. The greater the bending, the stronger the stress on the cranial base and the higher the risk of bone fractures. Consequently, microfractures can injure the vulnerable structures passing through cranial foramina (round foramen, maxillary nerve, oval foramen, mandibular nerve; superior orbital fissure, accessory meningeal artery, superior ophthalmic vein, inferior ophthalmic vein, oculomotor nerve, trochlear nerve, three branches of the ophthalmic nerve, and abducent nerve). However, bone elasticity protects against stress and fractures and decreases with patients' skeletal age. At the juvenile cranial base, with a lateral bend of 2.5 mm in the pterygoid process, the stress was between 61.3 and 186.3 MPa. In contrast, it amounted to 210.2–426.8 MPa at the adult cranial base. Therefore, rapid maxillary expansion not surgically assisted is a high-risk procedure in adult individuals.

Conversely, there is a lower age limit for beginning the treatment. Following the results published by Thilander *et al*.,[20] the right timing for rapid maxillary expansion corresponds to early mixed dentition after first permanent molars have fully erupted. An early expansion for cross-bite, during the deciduous dentition stage, is contraindicated because a lateral crossbite in the deciduous dentition cannot necessarily be associated with a crossbite in the mixed dentition. Therefore, at this stage of development, rapid maxillary expansion has been classified as over-treatment. The only treatment proposed is an occlusal modification by tooth grinding or by bite-blocks on the deciduous dentition.

During this period, between the early mixed and full permanent dentitions, the pubertal peak in skeletal maturation was analyzed as a cut-off, which could influence the response to expansion. Relative to the long-term, Baccetti *et al*.[21] reported a greater orthopedic effect (increased maxillary skeletal width, lateronasal width, and latero-orbitale width) in patients with expansion before the peak than in those treated subsequent to the peak.

We focused our analysis on changes in the dental arch after maxillary expansion.[5] A treatment performed in the early mixed dentition was identified as one of the favorable conditions for dental arch width stability, especially in intercanine and intermolar areas, in patients treated for a lateral crossbite. In other words, male children with a lateral cross-bite that expanded in the first transitional period,[22] that is, before maxillary lateral incisors had fully erupted, showed no relapse in dental arch dimension and form 2 years and 4 months after the end of treatment and the cessation of retention. On the contrary, a later expansion together with female gender and the absence of a lateral crossbite were classified as negative exposures for dental arch form stability over time.

In addition, another important aspect of the treatment procedure is retention time. After disarticulation, it is necessary to wait for suture ossification before removing the expander. As previously reported, the opening is triangular, with a greater gain in width in the anterior area than in the molar area.[8] Therefore, the time needed for ossification can vary from the anterior to the posterior area. Vardimon *et al*.[10] estimated 5 months for the molar area and 10 months for the anterior area. On the other hand, in a previous paper, Ekström *et al*.[23] indicated 3 months as retention time after expansion. However, they analyzed patient responses only by means of radioisotopes. More recently, Lione *et al*.[24] defined 6 months as the global time needed for bone deposition in all parts of the suture.

EXPANSION APPLIANCE DESIGN AND ANCHORAGE

In 2013, Zuccati *et al*.[25] reviewed randomized clinical trials focusing on the effectiveness of different types of expander designs. In general, at 6-month follow-up, the expansion effect was similar in patients treated by means of rapid maxillary expanders with different anchorage designs (tooth-borne anchorage, tooth tissue-borne anchorage, skeletal anchorage, acrylic bonded anchorage, two- vs. four-band anchorage) and the quad helix. The only condition for equivalence in results was an equal expansion force generated by the screws. However, a meta-analysis was not performed because data reported in the reviewed papers were heterogeneous with a high risk of bias. Therefore, the authors did not reach a definitive conclusion.

Many of the papers published about maxillary expansion were aimed at identification of a better expander that allowed for opening the midpalatal suture without the side-effect of dentoalveolar proclination.

For example, Oliveira *et al*.[26] compared the Hyrax with the Haas expander. They concluded that the combined tissue-borne anchorage provided by the Haas expander increased the orthopedic effect. On the contrary, the expansion produced by the Hyrax appliance, with an exclusively tooth-borne anchorage, resulted from a combination of alveolar bone and molar tipping and not from a predominant effect on the midpalatal suture.

Lagravère *et al*.[27] evaluated the effectiveness of skeletal anchorage by two screws inserted into the bicuspid-molar area, replacing the traditional dental anchorage provided by the Hyrax design. No significant difference was observed 6 months after the end of treatment. However, the most relevant negative result was the presence of dentoalveolar proclination in the patients treated with the expander anchored exclusively by means of screws. The degree of molar tipping was equal in both groups. However, when Mosleh *et al*.[28] modified the anchorage design by adding dental anchorage to first molars with skeletal anchorage by screws in the bicuspid region (bone-borne maxillary Hyrax expander), the dental and alveolar proclination was reduced and reached the highest level in patients treated only with the traditional Hyrax (tooth-borne maxillary Hyrax expander). Therefore, the clinical option of skeletal anchorage is not based on sound scientific evidence and as reported by Lagravère *et al*. in his editorial in the American Journal of Orthodontics and Dentofacial Orthopedics,[27] is the second choice after traditional appliance design only when available dental anchorage is not adequate.

With regard to dental anchorage, some authors have confirmed the effectiveness of expanders bonded to deciduous molars instead of permanent molars.[3-8,24,29] In particular, the stability of expansion was checked during a follow-up longer than that of treatments with the expander skeletally anchored.

A comparison between expanders anchored to deciduous versus permanent dentition was performed by Ugolini *et al*.[30] in a randomized clinical trial. The three-dimensional (3D) analysis of dental casts showed a significant increase in transverse widths in both groups. However, it must be noted that the highest net amount of expansion was reached in the group with the expander anchored to deciduous dentition, especially in intercanine area. Moreover, molar tipping was more pronounced in the group with anchorage to first permanent molars.

In addition, the clinical choice of this alternative deciduous anchorage can be supported by the evidence for reduced risk of side-effects in the permanent dentition and periodontal tissues as a consequence of the high forces exerted by the expander screw[9] and/or by plaque accumulation:

1. Root resorption;[10-12]
2. Bone loss;[13,14] and
3. White-spot lesions.[15]

With regard to the side-effects on alveolar bone, however, there is no clear evidence, because data published in the literature are not always consistent. In fact, Lione *et al*.[31] published a literature review in which they concluded that the thesis of bone loss as a side-effect after rapid maxillary expansion cannot be accepted.

In conclusion, anchorage to deciduous dentition is motivated by the effectiveness of dental arch widening, and its stability is preserved in the middle and long-term.[3-8] Second, it can reduce the negative side-effects produced by expansion on permanent dentition because the anchoring deciduous teeth will be lost.

Conversely, analysis of the recently reported data about equivalence in the effectiveness of anchorage to deciduous dentition and gold standard anchorage to permanent molars[30] could induce clinicians to prefer the new option for reduced risks.

DENTAL EFFECT OF A RAPID MAXILLARY EXPANDER ANCHORED TO DECIDUOUS TEETH

Intermolar width

The primary aim of rapid maxillary expansion is the increase of intermolar width to correct a lateral crossbite. A secondary aim is the widening of a constricted maxillary arch.[8,32]

We have estimated the changes in intermolar width measured at first permanent molars in a group of patients after expansion performed with a Haas expander anchored exclusively to deciduous teeth.[5] The amounts of variation differed between patients with and those without a lateral crossbite. Two years and 4 months after the end of treatment, and the cessation of retention, the patients with a previous lateral crossbite kept 3.9 mm of 4.9 mm initial expansion. On the contrary, in the group of patients without a lateral crossbite, the initial expansion of 2.6 mm was reduced to 1.5 mm in the same time interval.

When we compared our results with those of a 3D analysis performed by Ugolini *et al.*[30] in patients treated for a lateral crossbite with an expander anchored to deciduous teeth, we found that the intermolar width showed a similar change, with an increase of 4.4 mm maintained in the short-term.

However, the most relevant question relates to the stability of expansion until the stage of permanent dentition is achieved in comparison with the change produced by growth in the absence of treatment for a lateral crossbite. Moreover, in the final analysis of estimated intermolar width of treated patients, the increase produced by growth must be differentiated from treatment effects. From a theoretical point of view, we can hypothesize, at the end of growth, an increment of intermolar width resulting from the sum of treatment expansion and growth.

As reported by Sillman,[33] the increase in intermolar width during mixed dentition is not as pronounced, because it occurs mainly in the deciduous dentition.

Hesby *et al.*[34] reported an increase of 2.8 mm in children between the ages of 7.6 and 12.9 years. They used as reference points the most gingival point on the contour of the distal margin ridge of the maxillary permanent first molars. As the same authors reported in a previous paper,[35] maxillary molars erupt with a buccal torque and then move lingually with age. The opposite movement occurs in the mandibular arch. Over this period of time, maxillary and mandibular intermolar widths increase. In particular, in the maxillary arch, the movement of the molar apex is greater than that of the crown, which explains why intermolar distance widens.

To check the effect of expansion preserved in the stage of permanent dentition, we followed, retrospectively for 4.1 years, a group patients treated exclusively with a Haas expander in early mixed dentition[7] for a lateral crossbite [Figure 1]. The relapse was nonsignificant (0.5 mm), and the net increase amounted to 4.6 mm. A similar result was obtained by Lima *et al.*[36] in patients treated at the age of 8 years and 2 months with a traditional expander anchored to permanent molars. A final increase of 4.5 mm was measured 4 years after the end of treatment.

In the same study, we compared the patients treated early for cross-bite at the follow-up in permanent dentition with two groups of untreated adolescents and adults in dental Class 1 and without a lateral crossbite and one group of adolescents with a lateral crossbite and a dental class homogenous with that of the treated patients before treatment. The aim was to establish whether the treatment had modified the dental arch dimension toward the value of untreated "ideal" patients and in cases of absence of treatment if the intermolar width remained constricted.

Results confirmed treatment effectiveness: The patients with expansion reached intermolar width equal to that of untreated adolescents and adults with normal occlusion. Moreover, it must be noted that relapse after treatment was so minimal that treated patients just at the end of treatment in mixed dentition presented an intermolar width not different from that of older control individuals in normal occlusion measured at the end of growth. Therefore, we can hypothesize that growth in intermolar width was not relevant after the end of treatment. On the contrary, the untreated individuals with a lateral

Figure 1: Case report. Female patient treated for a lateral cross-bite at age 8 years and 2 months with a rapid maxillary expander anchored exclusively to deciduous dentition and followed until the permanent dentition stage. (a) Pretreatment (age, 8 years and 2 months). (b) End of expansion after 25 days' screw activation (0.2 mm/day). (c) Appliance removal, after 13 months. (d) Follow-up at 4 years and 3 months after debonding and the cessation of retention

crossbite maintained a reduced intermolar diameter, narrower than that of treated patients and individuals in normal occlusion. Conversely, the control individuals without a lateral crossbite and with the same dental class as treated patients before treatment showed intermolar width slightly more narrow than that of treated patients and untreated persons in dental Class 1.

To evaluate the intermediate change at the late mixed dentition stage, we performed the same study design,[6] comparing a similar group of treated patients in early mixed dentition at the follow-up in late mixed dentition with two groups of untreated individuals with and without a lateral crossbite and a canine dental class homogeneous with that of treated patients before treatment and a group of adolescents in dental Class 1 without a lateral crossbite. We reached the same conclusions as reported in the previous paper.

Therefore, the persistence of a lateral crossbite was obstacle in the physiological development of intermolar width, and the patients treated early achieved a diameter equal to that of individuals with normal dental occlusion. The increase produced showed no relapse until the end of dental arch growth.

In conclusion, rapid maxillary expansion with anchorage to deciduous dentition is effective for the correction of a lateral crossbite and to achieve physiological intermolar width.

Intercanine width and anterior crowding

Early rapid maxillary expansion also modifies intercanine width in patients with a lateral crossbite. Patients treated in the first period of transition, that is before lateral incisors had fully erupted, showed, at the follow-up in permanent dentition, a diameter equal in dimension to those of adolescents and adults in dental Class 1 without a lateral crossbite.[7] In contrast, control groups of individuals with a lateral crossbite preserved a significant reduction in intercanine width both in late mixed[6] and in permanent dentition.[7]

Therefore, rapid maxillary expansion corrects an intercanine transverse deficiency in patients with a lateral crossbite and re-establishes a normal growth trend with responses similar to those recorded in the intermolar area.

However, when we evaluated the net increase in intercanine width, it was influenced not by the presence of a lateral crossbite but by treatment timing. In a short time, at the 2- and 4-month follow-ups, we measured a significant increase in intercanine width in patients with (mean, 3.3 mm) and without (2.7 mm) a lateral crossbite.[5]

Favorable exposure was identified in the young dental age. The patients treated with expanders before lateral incisors had fully erupted (first period of transition)[22] showed increased intercanine width of 3.5 mm compared with 1.6 mm in patients treated after the eruption of lateral incisors (inter-transitional period). It must be noted, however, that the intercanine width reached the same length in both groups and showed the same degree of relapse. In fact, the difference in net increase resulted from the narrower diameter in the youngest patients before treatment relative to that of older patients: 28.6 mm of intercanine width in the first group versus 31.3 mm in the second.

The initial difference can be explained as the result of growth occurring during the eruption of maxillary incisors. As reported by Moorrees *et al*.,[37] the intercanine widths grow mainly during the eruption of incisors and to a lesser degree during the eruption of cuspids. They estimated an increase of 3.8 mm in the period between the ages of 7 and 12 years. Sillman[33] described growth in the intercanine diameter up to 13 years of age. However, he identified a spurt during deciduous dentition (0–4 years).

Consequently, the increased intercanine width measured in the youngest patients was no greater than that normally recorded during dental arch growth. It was the same increment as that obtained in a shorter period than usual by means of the rapid opening of the suture produced with the treatment.

Moreover, following the results published by Ugolini *et al*.,[30] the anchorage to deciduous dentition produced a more stable expansion, specifically in the anterior area, relative to that produced by the traditional anchorage design on permanent molars.

The rapid increase in intercanine width is favorable because, in only 1 month of screw activation, the diameter widened, and new space was made available for crowded teeth.

In fact, in our analysis[6] of the anterior irregularity index,[38] the patients receiving expansion treatment in the early mixed dentition (first transitional period) showed, in follow-up at 9 years of age, an irregularity index (median, 2.4 mm) lower than that of untreated individuals with (median, 3.2 mm) and without (median, 4.0) a lateral crossbite.

The same comparison performed at the follow-up in the permanent dentition[7] showed that the advantage of early expansion was still present: 56% of untreated adolescents with a lateral crossbite had an anterior irregularity index higher than 5 mm versus 11% of patients treated early for a lateral crossbite. In addition, the individuals without a lateral crossbite, homologous for canine dental Class with treated patients before expansion, had a prevalence of 33% of an irregularity index higher than 5 mm. Those patients fell between the two groups of treated and untreated individuals for lateral crossbite, and the difference did not reach the level of significance in each of two-by-two comparisons.

The improvement in anterior crowding should be evaluated as a positive effect, even when it is not a complete resolution. In fact, as reported by Surbeck *et al*.,[39] severe crowding is a negative risk factor for relapse after orthodontic treatment.

The reduction in the irregularity index can be explained as the effect of the rapid increase in intercanine arch length produced by the expansion (mean value, 6.8 mm), a consequent eruption of better-aligned incisors, and an insertion of transseptal fibers in less-rotated teeth.[40] This conclusion confirms the results of Canuto *et al*.[41] about the ineffectiveness of rapid maxillary expansion performed in permanent dentition for improving stability in anterior alignment after fixed orthodontic treatment.

In addition, in the specific clinical condition of permanent incisor cross-bite, a spontaneous correction was recorded in 84% of cases after early rapid maxillary expansion with anchorage to deciduous dentition.[29]

Furthermore, the transverse increase in molar area cannot be included in estimations of dental arch length increase.

Hnat *et al*.[42] had forecast the arch length change for different increments in width, using a model based on combined beta and hyperbolic cosine functions. Assuming a triangular suture opening and, therefore, a ratio of expansion between canine and molar area of 1.25:1 and 1.5:1, increased arch length occurs in the anterior area only. In the posterior area distal from cuspids, the curve becomes flatter and shorter than before expansion. If we assume an equal expansion in anterior and posterior areas, the increase in arch length is 95% in the anterior area and only 5% in the posterior area.

In the model Germane *et al*.[43] applied to the mandibular arch, molar expansion higher than 5 mm is needed to solve 2 mm crowding. In contrast, an increase of 2 mm in arch length can be produced by 2 mm of incisor or 2.5 mm of cuspid proclination.

Those mathematical details, together with the results published by Ugolini *et al*.,[30] provide further justification for the use of an expander anchored to deciduous dentition, which allows for modification of the anterior area in a greater and more stable way than that provided by the traditional expander anchored to permanent molars.

CONCLUSIONS

1. Rapid maxillary expansion aiming to correct a lateral crossbite must be performed during skeletal growth,

after the eruption of first permanent molars and before the end of adolescence
2. Rapid maxillary expansion with anchorage to deciduous dentition is effective in increasing transverse width in intermolar and intercanine areas, and the change is preserved until the full permanent dentition stage
3. An early expansion, before maxillary lateral incisors have fully erupted, allows for rapid increase in the arch length in the anterior area and consequently, in the space available, with a concomitant reduction in crowding
4. Anchorage to deciduous teeth produces a more pronounced and stable expansion in the anterior area, with a reduction in the risk of negative side-effects on the dentition, than the traditional expander anchored to permanent molars.

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Conflicts of interest
There are no conflicts of interest.

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