Hyrax versus Leaf expander in growing patients, what about adverse dental effects? A retrospective study

Sacha Benhamour, Damien Brézulier

▶ **To cite this version:**

Sacha Benhamour, Damien Brézulier. Hyrax versus Leaf expander in growing patients, what about adverse dental effects? A retrospective study. International Orthodontics, 2022, 20 (4), pp.100684. 10.1016/j.ortho.2022.100684 . hal-03798792

HAL Id: hal-03798792
https://hal.science/hal-03798792

Submitted on 14 Dec 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Hyrax versus Leaf expander in growing patients, what about adverse dental effects? A retrospective study

Abstract

Objectives:

Transverse discrepancy is a common problem in young patients. Many devices are employed to expand the palatal dimension, with different characteristics and biomechanical aspects. The Leaf Expander, a newborn appliance containing nickel-titanium springs, free from activation by parents. We compared Leaf Expander's dental effects to conventional Hyrax's ones, in growing patients.

Methods:

All patients who met the eligibility criteria were included between the period from January 2017 to December 2019. The patients had transverse inter-arch discrepancy of at least 5 mm and were treated with Hyrax expander (HEX) or Leaf expander (LEX). All patients had complete follow-up of expansion by remote monitoring. An algorithm established distances between the teeth. It was also used to measure the change in tooth axis.

Results:

In the maxilla LEX caused more tipping on the canines and premolars but significantly less on the molars compared to the HEX: -0.154° vs. 3.05° ($p < 0.001$). In the mandible, LEX caused a greater increase in arch widths and tipping ($p < 0.02$) in the molars and second premolars, but not in the other teeth. No correlation was demonstrated between mandibular dental movements and increased maxillary arch widths. Alternatively, for the two devices, expansion and tipping were correlated within each dental arch ($r > 0.4$).

Conclusions:

The LEX produced on average more tooth movements than the HEX, except the maxillary first molars. Several correlations exist between the movements within each arch for the two devices, most often between tipping and expansion.

Key-words:

Functional; digital models; palatal expansion techniques; hyrax; leaf expander.

Introduction

Maxillary transverse discrepancy affects 8 to 18% of orthodontic patients. It results in a unilateral or even bilateral crossbite leading to a kinetic deviation of the mandible causing masticatory, aesthetic, skeletal and dental disorders [1]. Expansion of the maxillary arch with a fixed appliance is a well-known and established practice in clinical orthodontics, but current findings in "evidence-based dentistry" have not yet identified an ideal clinical expansion protocol. Thus, the choice of appliance type based solely on its ability to resolve maxillary constriction problems is no longer relevant. The orthodontist should, based on timing, choose a "patient-oriented" appliance that can minimize the various possible side effects, such as appliance breakage, functional impairments, periodontal tissue injury and, of course, pain [2].

Alongside the conventional rapid palatal expander known as HEX, the LEX has been proposed as a measure to overcome parents' cooperation. In addition, it ensures a much less painful treatment [3,4]. This is an expansion screw using moderate continuous forces generated by Ni-Ti leaves acting as springs [5]. The literature on this device is rich. The kinetics of action of the LEX are different: the expansion lasts several months. During this slow expansion, the mineralization of the intermaxillary suture is faster and even begins concomitantly with the expansion, making it more consistent with histo-physiology [6,7]. The vascular development would promote a rapid neo-ossification [8].

Although Hyrax and Leaf expanders seek orthopedic action, they are bonded to the first molars with two bands. As tooth-borne devices, they intrinsically cause unwanted tooth movements. Furthermore, the relationships between arches are at the origin of the transmission of

unwanted effects from the maxillary teeth to those of the mandible [9]. These tooth movements can alter the gums and roots of the mandible, but can also generate space. To our knowledge, only one randomized clinical trial has compared these two appliances on the dental level. However, it did not study the dental effects on the mandible [10]. It is interesting to discuss the mandibular effects since mandibular expansion combined with maxillary rapid expansion could lead to significantly more favorable results than a HEX protocol alone [11]. Additionally, studies comparing HEX and LEX concerning mandibular dental effects have not been reported in the literature yet.

In this context, the primary objectives of this retrospective cohort study were: to compare the dental effects on the maxilla and on the mandible of these two types of expanders. The secondary objective was to test the existing correlations between the different dental parameters for each of these types of treatment in pre-teens patients.

1 Material and Methods

1.1 Participants

The Ethics Committee of the XXXXX Hospital gave its approval for this retrospective study (Opinion n° 21.67). Data from 89 patients treated consecutively for maxillary expansion, in the orthodontic department of the XXX Hospital between January 2017 and December 2019 were used. All of these patients had been diagnosed with transverse maxillary discrepancy. Inclusion criteria were as follows: (1) beginning treatment between 7 and 13 years old; (2) maxillary constriction with posterior uni or bilateral crossbite; (3) maxillomandibular transverse discrepancy greater than 5 mm in the first molars; (4) radiolucent spaces between the outer edges of the maxilla and the mandibular ramus on frontal radiography; (5) maxillomandibular width differential according to Ricketts and Betts greater than 14 mm; (6) patients treated with either a Hyrax or a Leaf expander of 900g; and (7) patients whose treatment was followed by the Dental Monitoring tool. Exclusion criteria were as follows: (1) cranio-facial abnormalities (clefts, syndrome); (2) patients exhibiting poor oral hygiene; (3) previous or other orthodontic treatment; (4) preexisting gingival recessions; (5) loss of appliance; and (6) missing data such as models or X-ray.

1.2 Expanders design and activation rates

All patients were treated with a maxillary expander bonded to the first molar with two bands (Ketac CEM 3M). Patients were divided into two groups depending on the appliances used:

- HEX cohort: A Hyrax Expander (Dentaurum, Germany), consisting of a 10 mm cylinder and two arms in contact with the premolars (or temporary molars) and canines.
- LEX cohort: A Leaf Expander (Leone, Italy) with a 900g nickel-titanium spring.

Both expanders used were made by the same technician according to a standard scheme. Briefly, the devices were located directly above the resistance centers of the maxillary molars or as close as possible to the mucosa. The arms of the devices were welded to the bands and then applied to the palatal surfaces of the premolars and canines. The activation patterns were as follows: for HEX, two activations per day and for LEX 10 activations per month. Reactivation of the LEX is performed in the office. A quarter turn corresponds to 0.1 mm of activation [5]. The starting point for patient follow-up (T0) corresponded to the day of insertion and the start of activations after explanations.

1.3 Digital models' analysis

Measurements were made using two methods. A first step was conducted on the Trios 4 impressions (3Shape). In a second step, the measurements were made from the data of the remote monitoring.

All the patients included were followed by the Dental Monitoring application. The follow-up was regular, every 4 days. The activation phase was stopped to obtain contact between the palatal cusps of the first maxillary molars and the vestibular cusps of the first mandibular molars when the patient was biting in Angle Class I. For the LEX group the spring was embedded in composite to stop the activity. At the end of the activation phase, a stabilization phase of 1 month for the LEX and 3 months for the HEX was performed. The passive device was left in place. The final measurements (T1) were made after the stabilization phase.

The application made it possible to track changes in tooth position. Specifically, the algorithm was used to establish the distances between the buccal cusps of the teeth. It was also used to

measure the change in tooth axis: the difference between the perpendicular to the occlusal plane and the tooth axis at T0 and T1.

The calculation of method error was not performed because the data were derived from an algorithm and not from a human examiner.

1.4 Outcomes

The following parameters were examined both for maxillary and mandibular arches:

- Width between teeth, from canines to molars, measured between mesio-buccal cusps;
- Dental tipping, from canines to molars; the values retained were the average of the left and right sides. Tipping was the change in tooth axis, i.e., the difference between the perpendicular to the occlusal plane and the tooth axis at T0 and T1;
- The dental arch perimeter, distance from the distal of the first permanent molar on one side to the same surface on the opposite side;
- Duration of treatment of active phase

1.5 Statistical analysis

Statistical analysis was performed with RStudio version 1.2.5001 (RStudioTeam) with R 3.6.1 (RCore Team). Qualitative data were analyzed by Pearson's chi2 test. The means were compared by Student's t test, after testing the equality of variances and normality, with Bonferroni adjustment for multiple comparisons (= 0.05). Pearson's correlations were used. P values ≤ 0.05 were considered significant.

With 28 and 24 measurements in the groups, a post hoc power calculation for unpaired two tails t-tests conducted using the statistical tool G*Power (Version 3.1.9.4), indicates a power of 82% to detect a large effect size (Cohen's d = 0.80) at a significance level of 0.05.

2 Results

2.1 Inclusion of patients

89 patients were selected. In the HEX group, 11 had missing data, mainly in the follow-up with Dental Monitoring and 5 were lost. For the LEX group, 14 patients were excluded for lack of data

and 5 for discontinuation of follow-up, mainly due to the loss of the device. This leaves a sample of two groups of 26 and 28 patients with a sex ratio of 1:1 and a mean age of 10.2 years (Figure 1).

2.2 Comparability of groups

The first step was to check the initial comparability of the groups. It was validated in terms of age, sex, arch widths and perimeters (Table 1).

2.3 Duration of the active phase of treatment and whole expansion

Patients in the HEX group had a significantly shorter active phase (15.8 ± 3.4 days versus 134.4 ± 22.1 days) ($p < .0001$). The expansion rates were 0.35 mm/day for HEX and 0.27 mm/week for LEX. The total duration of wearing the device (T0 to T1) was close in the two groups, of the order of 4 months.

2.4 Effects on maxillary teeth

The arch perimeter has increased from 96.5 ± 5.63 to 100.3 ± 6.65mm in the HEX group and from 95.9 ± 4.57 to 99.9 ± 5.08mm for LEX. Within each group, this increase was significant ($p < 0.0001$). However, no difference was found between groups ($p > 0.9$).

If we focus on the arch widths, the variations ranged from 3.98 ± 1.80 to 5.57 ± 1.27mm for HEX and from 4.54 ± 2.31 to 6.65 ± 2.26mm for LEX. However, there was no significant difference between groups except at the level of the first premolars ($p = 0.4$). Here, the increase for LEX was 6.65 ± 2.26mm while it was only 5.30 ± 2.03mm for HEX.

The tipping values appeared disparate between groups. For HEX, they fluctuated from 3.05 ± 1.98 to 5.55 ± 2.65° while for LEX, the interval went from -0.154 ± 1.52 to 12.5 ± 3.31°. When analyzed more closely, the premolars were the most exposed teeth in the HEX group. Alternatively, the canines and first molars suffered a weak tipping. For LEX, the canines and second premolars had a similar buccal tipping of about 9 °. The first premolar had a strong tipping reaching 12 °. Conversely and interestingly, the molars did not undergo any movement, except for a slight straightening of the axis. Nevertheless, except for the second premolar, the

158 tipping was statistically different between groups ($p < 0.001$). The LEX caused few 2nd order
159 movements on the molars but much more on the other teeth (Table 2).

160 ## 2.5 Effects on mandibular teeth

161 The arch perimeter increased from 90.49 ± 5.28 to 90.86 ± 5.47mm in the HEX group and from
162 89.29 ± 3.97 to 89.62 ± 4.31mm for LEX. This increase in the order of 0.3mm is not statistically
163 significant.

164 If we now consider the arch widths for the HEX group, all of them increased similarly from 0.364
165 to 0.493mm. In contrast, for the LEX cohort, the widths increased more in the posterior part of
166 the arch than in the front. The canine to canine width progressed by 0.530 ± 0.843mm, while
167 that at the level of the molars grew by 1.54 ± 0.822mm. A comparison of the two groups
168 revealed significant differences in the modification of arch widths between the first molars and
169 the second premolars but not for the first premolars and canines.

170 The tipping values for the HEX group have always remained below the 2.0° threshold. The
171 highest value was found for the second premolar (1.96 ± 2.25°). For the LEX group, the tipping
172 degrees ranged from 3.76 ± 2.76° to 1.10 ± 1.87°. Note that, for both groups, the most
173 important movement was found for the second premolar and then for the first molar. If we
174 compare the two groups, the tipping was more important for the LEX and this significantly for
175 the molars (Table 3).

176 ## 2.6 Data correlation for each device

177 For HEX, few parameters appeared to be correlated. The analysis demonstrated a strong
178 correlation between the increase in inter-dental distances and tipping. In the maxilla, the
179 Pearson correlation coefficient was greater than 0.45 and increased in the anterior part of the
180 arch. In the mandible, it fluctuated between 0.58 and 0.72. At both arches, the strongest
181 correlations between tipping and expansion were found for canines and molars. We can also
182 see that the expansion and tipping of the premolars was positively correlated with the
183 expansion of the molar level ($r > 0.4$). Other values were highlighted: the variation in the
184 perimeter of the maxillary arch was positively correlated with both that of the mandibular arch
185 ($r = 0.51$) and with the increase in the width between maxillary teeth ($r > 0.41$) (Figure 2).

For LEX, many more variables seemed correlated. However, only a couple of those had a biological rationale. Expansion and tipping were also correlated. In the mandible, the correlation was forceful ($r > 0.73$). The lowest coefficient was found for the molars. In the maxilla, the coefficients varied from 0.4 for the molars to 0.86 for the first premolars. It is interesting to note that the variations in the dimensions of both arches are not correlated. However, the increase in the perimeter of the maxillary arch is strongly linked to the expansion between the maxillary teeth ($r > 0.58$). The tipping of the mandibular molars was also correlated with the parameters qualifying the mandibular premolars ($r > 0.54$) (Figure 3).

One particular element must also be highlighted. In no case were the movements of the mandibular teeth correlated with the increase in arch width at the level of the maxillary molars.

3 Discussion

The maxillary expansion is the most common orthopedic procedure to correct transverse discrepancy and posterior crossbite [12]. Many studies have analyzed the effects of slow and rapid expansion with variable devices: Haas, Hyrax, quad'helix or removable device [13,14]. Rapid expansion using a Hyrax expander is the most prescribed technique currently [15]. However, Martina shows that using this device with a slow or fast activation rate makes no difference in terms of expansion [9]. In our study, the LEX was used to do the slow expansion. We have chosen to study it because according to the literature, it offers many advantages: continuous and low intensity forces (900gr), freedom of patient cooperation and it is more comfortable for pediatric patients [4,5,16]. Its effectiveness in opening the mid-palate suture has already been demonstrated by CBCT [17,18]. Like any tooth-borne device, it potentially causes undesirable effects. The consequences of these movements are numerous, such as the weakening of the alveolar bone [19]. To date, few studies has compared the dental effects of these two devices in the maxilla, let alone the mandible. The outcome of this retrospective study was therefore to describe more precisely the arch modifications resulting from rapid expansion by HEX or slow by LEX in pre-teens patients.

In our study, measurements were made using two methods. The first method was through digital impressions; the 3Shape TRIOS® system has an accuracy of 42.9 ± 20.4µm [20]. The second

method was the Dental Monitoring (DM) algorithm. A 2019 study compares the measurements given by the algorithm to those on plaster models during expansion. The data are recorded at both the inter-canine and molar distances. The comparable results attest to the reliability of this method [21]. Additionally, a recent study concluded that 3-Dimensional models generated by DM were sufficiently accurate enough for clinical application [22]. Beyond these studies, few papers have focused on the precision of DM, but two other publications assure that the system allows the optimization of aligner treatments. Without the necessary precision, especially in the posterior areas, this type of optimization would be counterproductive [23,24]. These are the reasons why we decided to use this innovative data collection solution.

Regarding the maxillary dental effects, the two devices had comparable effectiveness. These results are comparable to those obtained by a randomized controlled trial which showed no difference between HEX and LEX at the dental level, except on the inter-canine distance parameter [10]. A study using HEX showed comparable changes in inter-tooth distances and arch perimeter, except for canines, in a sample of equivalent average age [25]. However, it was higher than those found by Alves et al [26]. A CBCT study, performed on older patients, found values of this order [27]. The expansion rates were different between the groups but comparable to those found by Akkaya for slow and rapid maxillary expansion [28]. The tipping was more important with the LEX for teeth with a punctiform support of the appliance. The free tipping imposed by the front arms of the devices and the longer application time explained that. Alternatively, the tipping was not significant on the molars in the LEX group. The tipping of the first molars with HEX is close to that found in the Lagravère meta-analysis: 3.10° [29]. The tipping observed with LEX was less than that observed in the literature for slow expansion. Wong noted an average buccal tipping of 4° [1].The powerful forces, reaching 10 kg, applied by the HEX can explain that [30]. They may exceed the stiffness threshold of the appliance or produce a weakening of the buccal bone. In this regard, the results of the literature obtained from CT scans show that changes in alveolar heights around the first molars were insignificant during LEX expansion [19]. This is interesting because the correction of the dental compensation of the transverse discrepancy will be done by palatal tipping of the molars. It will be even simpler and less risky at the root

level that the buccal tipping will be limited [24]. However, LEX has more undesirable effects on other teeth, in particular tipping.

In the second part, we focused our work on the effects on the mandibular arch. A spontaneous response following rapid maxillary expansion has been described in the past [31,32]. For both groups, our results are comparable to the literature that reports an increase in the mandibular inter-molar distance [32]. Here, the LEX allows for straightening of the posterior tooth axes that is positively correlated with an increase in arch widths, which are greater than those observed for the HEX. In fact, the lingual tipping initially present is reduced. However, these variations do not result in a saving of space since the perimeter of the mandibular arch did not change significantly during the expansion in a group. In fact, the literature describes a decrease in mandibular arch length during adolescence [33]. More precisely, a decrease of up to 1mm has been demonstrated during the transition from deciduous to permanent dentition [34]. We can assume here that the dental movements imposed by the maxillary expansion erase this reduction of the arch perimeter.

The dento-alveolar effects were most significant on the molars and second premolars. This can be explained by the strong occlusal relationship between the molars and by the weak anchorage of the mandibular second premolars. The total durations of treatment were similar, but those of the active phases differed. The stresses applied to the mandibular teeth progressed slowly for LEX, which resulted in greater mandibular movements. This spontaneous correction concludes that the longer duration of the active phase in the maxilla allows the correction of mandibular teeth without the use of lower braces.

Nevertheless, this study had several limitations. First, one of the main weaknesses of retrospective studies is that they generate a large number of missing data. Here 35 patients had to be excluded because of missing data. Second, these data must be weighed against the fact that temporary and permanent teeth were pooled. Indeed, we did not conduct a subgroup analysis according to the stage of dentition. Replacement of temporary molars most often results in a change in tooth axis that is not qualified here. Third, although the data from remote monitoring using the Dental Monitoring algorithm is reliable, this type of protocol remains marginal, which makes the data acquired questionable, but allows us to validate the good

compliance in the HEX group. Prospective protocols will have to be proposed, probably with stratification on the stage of dentition, to decide on the dental effects of these appliances.

4 Conclusions

The objectives of this retrospective cohort study were to compare the dento-alveolar effects of HEX and LEX on both arches in growing patients. Four conclusions can be drawn:

- LEX did not produce significant tipping on the maxillary molars, but much more on the other teeth.
- In no case were the movements of the mandibular teeth correlated with expansion between the maxillary molars.
- The space saving in the mandible following maxillary expansion was negligible in both groups.
- There was a strong correlation between tipping and expansion at the mandible in the LEX group.

5 References

1. Wong CA, Sinclair PM, Keim RG, Kennedy DB. Arch dimension changes from successful slow maxillary expansion of unilateral posterior crossbite. *Angle Orthod*. 2011;81(4):616-623.

2. Needleman HL, Hoang CD, Allred E, Hertzberg J, Berde C. Reports of pain by children undergoing rapid palatal expansion. *Pediatr Dent*. 2000;22(3):221-226.

3. Ugolini A, Cossellu G, Farronato M, Silvestrini-Biavati A, Lanteri V. A multicenter, prospective, randomized trial of pain and discomfort during maxillary expansion: Leaf expander versus hyrax expander. *Int J Paediatr Dent*. 2020;30(4):421-428.

4. Nieri M, Paoloni V, Lione R, et al. Comparison between two screws for maxillary expansion: a multicenter randomized controlled trial on patient's reported outcome measures. *Eur J Orthod*. 2021;43:293-300.

5. Lanteri C, Beretta M, Lanteri V, Gianolio A, Cherchi C, Franchi L. The Leaf Expander for Non-Compliance Treatment in the Mixed Dentition. *J Clin Orthod JCO*. 2016;50(9):552-560.

6. Storey E. Tissue response to the movement of bones. *Am J Orthod Dentofacial Orthop*. 1973;64(3):229-247.

7. Ekström C, Henrikson CO, Jensen R. Mineralization in the midpalatal suture after orthodontic expansion. *Am J Orthod*. 1977;71(4):449-455.

8. Gianolio A, Cherchi C, Lanteri V. Rapid and slow maxillary expansion: A posteroanterior cephalometric study. *Eur J Paediat Dent*. 2014;15:415-418.

9. Martina R, Cioffi I, Farella M, et al. Transverse changes determined by rapid and slow maxillary expansion--a low-dose CT-based randomized controlled trial. *Orthod Craniofac Res*. 2012;15(3):159-168.

10. Paoloni V, Giuntini V, Lione R, et al. Comparison of the dento-skeletal effects produced by Leaf expander versus rapid maxillary expander in prepubertal patients: a two-center randomized controlled trial. *Eur J Orthod*. 2022;44(2):163-9.

11. O'Grady PW, McNamara JA, Baccetti T, Franchi L. A long-term evaluation of the mandibular Schwarz appliance and the acrylic splint expander in early mixed dentition patients. *Am J Orthod Dentofacial Orthop*. 2006;130(2):202-213.

12. Haas AJ. Rapid Expansion Of The Maxillary Dental Arch And Nasal Cavity By Opening The Midpalatal Suture. *Angle Orthod*. 1961;31(2):73-90.

13. Grassia V, d'Apuzzo F, Jamilian A, Femiano F, Favero L, Perillo L. Comparison between rapid and mixed maxillary expansion through an assessment of arch changes on dental casts. *Prog Orthod*. 2015;16(1):1-7.

14. Harrison JE, Ashby D. Orthodontic treatment for posterior crossbites. *Cochrane Database Syst Rev*. 2001;(1).

15. Ugolini A, Agostino P, Silvestrini-Biavati A, Harrison JE, Batista KB. Orthodontic treatment for posterior crossbites. *Cochrane Database Syst Rev*. 2021;12:CD000979.

16. Ulug B, Arman Özçırpıcı A. Early Maxillary Expansion with the Ni-Ti Memory Leaf Expander-A Compliance-Free Fixed Slow Maxillary Expansion Screw: A Report of 2 Cases. *Turk J Orthod*. 2021;34(2):143-149.

17. Lanteri V, Farronato M, Ugolini A, et al. Volumetric Changes in the Upper Airways after Rapid and Slow Maxillary Expansion in Growing Patients: A Case-Control Study. *Materials*. 2020;13(10).

18. Lanteri V, Gianolio A, Gualandi G, Beretta M. Maxillary tridimensional changes after slow expansion with leaf expander in a sample of growing patients: a pilot study. *Eur J Paediatr Dent*. 2018;19(1):29-34.

19. Garib DG, Henriques JFC, Janson G, de Freitas MR, Fernandes AY. Periodontal effects of rapid maxillary expansion with tooth-tissue-borne and tooth-borne expanders: a computed tomography evaluation. *Am J Orthod Dentofac Orthop*. 2006;129(6):749-758.

20. Ender A, Attin T, Mehl A. In vivo precision of conventional and digital methods of obtaining complete-arch dental impressions. *J Prosthet Dent*. 2016;115(3):313-320.

21. Moylan HB, Carrico CK, Lindauer SJ, Tüfekçi E. Accuracy of a smartphone-based orthodontic treatment–monitoring application:A pilot study. *Angle Orthod*. 2019;89(5):727-733.

22. Morris RS, Hoye LN, Elnagar MH, et al. Accuracy of Dental Monitoring 3D digital dental models using photograph and video mode. *Am J Orthod Dentofacial Orthop*. 2019;156(3):420-428.

23. Hannequin R, Ouadi E, Racy E, Moreau N. Clinical follow-up of corticotomy-accelerated Invisalign orthodontic treatment with Dental Monitoring. *Am J Orthod Dentofac Orthop*. 2020;158(6):878-888.

24. Hansa I, Katyal V, Ferguson DJ, Vaid N. Outcomes of clear aligner treatment with and without Dental Monitoring: A retrospective cohort study. *Am J Orthod Dentofacial Orthop*. 2021;159(4):453-459.

25. Maspero C, Cavagnetto D, Fama A, Giannini L, Galbiati G, Farronato M. Hyrax versus transverse sagittal maxillary expander: An assessment of arch changes on dental casts. A retrospective study. *Saudi Dent J*. 2020;32(2):93-100.

26. Alves AC de M, Janson G, Mcnamara JA, Lauris JRP, Garib DG. Maxillary expander with differential opening vs Hyrax expander: A randomized clinical trial. *Am J Orthod*

Dentofacial Orthop. 2020;157(1):7-18.

27. Davami K, Talma E, Harzer W, Lagravère MO. Long term skeletal and dental changes between tooth-anchored versus Dresden bone-anchored rapid maxillary expansion using CBCT images in adolescents: Randomized clinical trial. *Int Orthod*. 2020;18(2):317-329.

28. Akkaya S, Lorenzon S, Uçem TT. Comparison of dental arch and arch perimeter changes between bonded rapid and slow maxillary expansion procedures. *Eur J Orthod*. 1998;20(3):255-261.

29. Lagravère MO, Gamble J, Major PW, Heo G. Transverse dental changes after tooth-borne and bone-borne maxillary expansion. *Int Orthod*. 2013;11(1):21-34.

30. Isaacson R, Ingram AH. Forces produced by rapid maxillary expansion : II. Forces present during treatment. *Angle Orthod*. 1964;34:261-270.

31. Sandstom R. Expansion of the lower arch concurrent with rapid maxillary expansion. *Am J Orthod Dentofacial Orthop*. 1988;94(4):296-302.

32. Lima AC, Lima AL, Filho RMAL, Oyen OJ. Spontaneous mandibular arch response after rapid palatal expansion: a long-term study on Class I malocclusion. *Am J Orthod Dentofac Orthop*. 2004;126(5):576-582.

33. Bishara SE, Jakobsen JR, Treder JE, Stasl MJ. Changes in the maxillary and mandibular tooth size-arch length relationship from early adolescence to early adulthood. *Am J Orthod Dentofacial Orthop*. 1989;95(1):46-59.

34. Stern S, Finke H, Strosinski M, Mueller-Hagedorn S, McNamara JA, Stahl F. Longitudinal changes in the dental arches and soft tissue profile of untreated subjects with normal occlusion. *J Orofac Orthop Fortschritte Kieferorthopädie*. 2020;81(3):192-208.

6 Captions

Figure 1: Flowchart of the patients included in this study, following CONSORT statement.

Figure 2: Correlogram of the various parameters related to the expansion by HEX. The coefficients presented are those of Pearson for a statistical significance at risk of 5%.

Figure 3: Correlogram of the various parameters related to the expansion by LEX. The coefficients presented are those of Pearson for a statistical significance at risk of 5%.

Table 1: Descriptive elements of groups at T0. The initial comparability was validated using Student's T tests and by Pearson's Chi2 at the 5% significance level.

Table 2: Evolution of measurements of maxillary arch perimeters, arch widths and tipping of teeth during treatment. The comparisons of the two groups were tested using Student's T tests at the 5% significance level and the Bonferroni correction for multiple testing (q-values).

Table 3: Evolution of measurements of mandibular arch perimeters, arch widths and tipping of teeth during treatment. The comparisons of the two groups were tested using Student's T tests at the 5% significance level and the Bonferroni correction for multiple testing (q-values).