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

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

3

4 Abstract

5 Objectives:

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

11 Methods:

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

17 Results:

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

24 **Conclusions:**

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

28 **Key-words:**

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

30 **Introduction**

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

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

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

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

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

## 63 1 Material and Methods

### 64 1.1 Participants

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

## 79 1.2 Expanders design and activation rates

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

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

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

## 93 1.3 Digital models' analysis

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

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

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

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

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

## 110 1.4 Outcomes

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

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

## 119 1.5 Statistical analysis

120 Statistical analysis was performed with RStudio version 1.2.5001 (RStudioTeam) with R 3.6.1  
121 (RCore Team). Qualitative data were analyzed by Pearson's chi<sup>2</sup> test. The means were compared  
122 by Student's t test, after testing the equality of variances and normality, with Bonferroni  
123 adjustment for multiple comparisons ( $\alpha = 0.05$ ). Pearson's correlations were used. P values  $\leq$   
124 0.05 were considered significant.

125 With 28 and 24 measurements in the groups, a post hoc power calculation for unpaired two  
126 tails t-tests conducted using the statistical tool G\*Power (Version 3.1.9.4), indicates a power of  
127 82% to detect a large effect size (Cohen's d = 0.80) at a significance level of 0.05.

## 128 2 Results

### 129 2.1 Inclusion of patients

130 89 patients were selected. In the HEX group, 11 had missing data, mainly in the follow-up with  
131 Dental Monitoring and 5 were lost. For the LEX group, 14 patients were excluded for lack of data

132 and 5 for discontinuation of follow-up, mainly due to the loss of the device. This leaves a sample  
133 of two groups of 26 and 28 patients with a sex ratio of 1:1 and a mean age of 10.2 years (Figure  
134 1).

## 135 2.2 Comparability of groups

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

## 138 2.3 Duration of the active phase of treatment and whole expansion

139 Patients in the HEX group had a significantly shorter active phase ( $15.8 \pm 3.4$  days versus  $134.4 \pm$   
140  $22.1$  days) ( $p < .0001$ ). The expansion rates were 0.35 mm/day for HEX and 0.27 mm/week for  
141 LEX. The total duration of wearing the device (T0 to T1) was close in the two groups, of the  
142 order of 4 months.

## 143 2.4 Effects on maxillary teeth

144 The arch perimeter has increased from  $96.5 \pm 5.63$  to  $100.3 \pm 6.65$ mm in the HEX group and  
145 from  $95.9 \pm 4.57$  to  $99.9 \pm 5.08$ mm for LEX. Within each group, this increase was significant ( $p <$   
146  $0.0001$ ). However, no difference was found between groups ( $p > 0.9$ ).

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

151 The tipping values appeared disparate between groups. For HEX, they fluctuated from  $3.05 \pm$   
152  $1.98$  to  $5.55 \pm 2.65^\circ$  while for LEX, the interval went from  $-0.154 \pm 1.52$  to  $12.5 \pm 3.31^\circ$ . When  
153 analyzed more closely, the premolars were the most exposed teeth in the HEX group.  
154 Alternatively, the canines and first molars suffered a weak tipping. For LEX, the canines and  
155 second premolars had a similar buccal tipping of about  $9^\circ$ . The first premolar had a strong  
156 tipping reaching  $12^\circ$ . Conversely and interestingly, the molars did not undergo any movement,  
157 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  $90.49 \pm 5.28$  to  $90.86 \pm 5.47$ mm in the HEX group and from  
162  $89.29 \pm 3.97$  to  $89.62 \pm 4.31$ mm 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  $0.530 \pm 0.843$ mm, while  
167 that at the level of the molars grew by  $1.54 \pm 0.822$ mm. 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  $2.0^\circ$  threshold. The  
171 highest value was found for the second premolar ( $1.96 \pm 2.25^\circ$ ). For the LEX group, the tipping  
172 degrees ranged from  $3.76 \pm 2.76^\circ$  to  $1.10 \pm 1.87^\circ$ . 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).



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

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

### 196 3 Discussion

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

212 In our study, measurements were made using two methods. The first method was through  
213 digital impressions; the 3Shape TRIOS® system has an accuracy of  $42.9 \pm 20.4\mu\text{m}$ <sup>20</sup>. The second

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

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

242 level that the buccal tipping will be limited <sup>24</sup>. However, LEX has more undesirable effects on  
243 other teeth, in particular tipping.

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

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

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

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

#### 273 4 Conclusions

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

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

284

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374

## 375 6 Captions

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

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

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

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

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

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