

## Comparison Among Three Fixed Palatal Expander Appliances: An in Vitro Study

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### الخلاصة

**الأهداف:** تحدد الدراسة إلى تقييم ثلاث موسعات للفك العلوي (حنكية) على التغيرات العرضية بين الضواحك الأولى والضواحك الثانية والرحى الأولى العلوية. **المواد وطرائق العمل:** قسمت العينة إلى ثلاث مجاميع. موسع الهايركس وموسع راعي الحلزون وموسع ديليو القوسي. أخذت صور قبل وبعد عملية التوسع وتم أخذ القياسات باستخدام برنامج أوتوكاد واستخدم إختباري الأنوفا ودنكن لتحليل البيانات. **النتائج:** بينت النتائج أن معدل التغيرات العرضية بين الضواحك الأولى والضواحك الثانية والرحى الأولى العلوية أظهرت فرقا معنويا بين موسع الهايركس وبقية الموسعات الحنكية بينما لم يوجد فرقا معنويا بين موسع راعي الحلزون وموسع ديليو القوسي. **الإستنتاجات:** موسع الهايركس أدى إلى توسع أكبر في القوس الفكّي العلوي من بقية الموسعات.

### ABSTRACT

**Aims:** To evaluate the effect of three different palatal expanders (Hyrax, Quad-Helix and W-Arch) on maxillary 1st premolar, 2nd premolar and 1st molar width changes. **Materials and Methods:** The sample consisted of three groups, the Hyrax (N=10), the Quad-Helix (N=10) and the W-Arch (N=10). Images were taken before and after expansion; analysis were made using Autodesk AutoCAD© program. One-way ANOVA and Duncan's multiple range tests were used ( $P \leq 0.05$ ). **Results:** Significant difference was found in the maxillary 1st premolar, 2nd premolar and 1st molar width changes between the Hyrax and the other two expanders, while there was no significant difference between the Quad-Helix and the W-Arch expanders. **Conclusion:** Maxillary arch width increases more consistently with the Hyrax expanders.

**Keywords:** Palatal expander, Hyrax, Quad-Helix, W-Arch.

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### INTRODUCTION

A common feature seen in orthodontic patients is a narrow or constricted maxillary arch<sup>(1)</sup>, in which the maxillary width is narrower than the norm for a particular age group.<sup>(2)</sup> The origin of a constricted maxilla can be skeletal, dental, or combination of both structures.<sup>(3)</sup>

Diagnosis of transverse skeletal discrepancy is difficult. There are various methods used to diagnose this condition. Clinical evaluation, model analysis, occlusograms, and radiographic measurements have been recommended for an accurate assessment.<sup>(4)</sup>

The correction of transverse maxillary deficiency can be an important component of an orthodontic treatment plan. A number of orthodontic techniques exist to ex-

pand the maxillary arch.<sup>(5)</sup> Increased maxillary arch width has been related to orthodontic movements, orthopedic movements, or a combination of these movements during expansion procedures.<sup>(6)</sup> Skeletal expansion involves separating the maxillary halves at the midpalatal suture, while dental expansion results from buccal tipping<sup>(7)</sup>, or bodily movement of the maxillary posterior teeth.<sup>(8)</sup>

Expansion of the palate was first achieved by Emerson C. Angell in 1860 and has been one of the oldest means of creating space in the dental arches<sup>(9)</sup>, to correct crossbites or expand arch perimeters to alleviate dental crowding.<sup>(10)</sup> One of the benefits of maxillary expansion is to minimize the need to extract teeth.<sup>(11)</sup>

Several orthodontic techniques and

expanders are available to expand the maxillary arch. Rapid maxillary expansion (RME), slow maxillary expansion (SME)<sup>(9)</sup>, semi rapid maxillary expansion (SRME)<sup>(12)</sup> and surgically assisted rapid palatal expansion (SARPE) can be used<sup>(13)</sup>. Palatal expanders can be removable or fixed, banded or bonded, tooth-borne or tooth and tissue-borne.<sup>(14)</sup>

The purpose of this study is to evaluate the effect of three different palatal ex-

panders (Hyrax, Quad-Helix and W-Arch) on maxillary 1<sup>st</sup> premolar, 2<sup>nd</sup> premolar and 1<sup>st</sup> molar width changes.

### MATERIALES AND METHODS

The sample composed of 3 groups. The first group consisted of Hyrax screw expanders, the second group consisted of Quad-Helix appliances and the third group was W-Arch appliances (Figure 1).



**Figure (1):** From above to bottom: Hyrax screw, Quad-Helix and W-Arch

#### A. Preparation of Typodont

A maxillary typodont wax form and metallic teeth were prepared according to manufacturer's instructions (Ormco, Japan) to be used in this study by removing the top and bottom metal plate and inserting the wax forms and then replacing the metal plates followed by inserting the teeth into the wax forms and pressing the teeth firmly into the wax.

Using rubber base impression material (heavy and light body) (Spofadent, Germany), an impression was taken for typodont; followed by pouring the impression with dental stone (Zhermack, Italy). Then the cast was used to construct the immobilization plate from acrylic resin (Major, Italy) which was used to fix the posterior and anterior buccopalatal section of this plate to the 2<sup>nd</sup> molars and anterior teeth and the surrounding simulated palatal surface of typodont wax. Then this plate was fixed to the metallic base using tightly fit

screw to the metal base of typodont.

After construction of immobilization plate, an impression was taken using rubber base impression material (heavy and light body) and poured with dental stone. The cast was used to construct the acrylic bite plane. This bite plane was used for repositioning premolars and first molars to their original position after each trial.

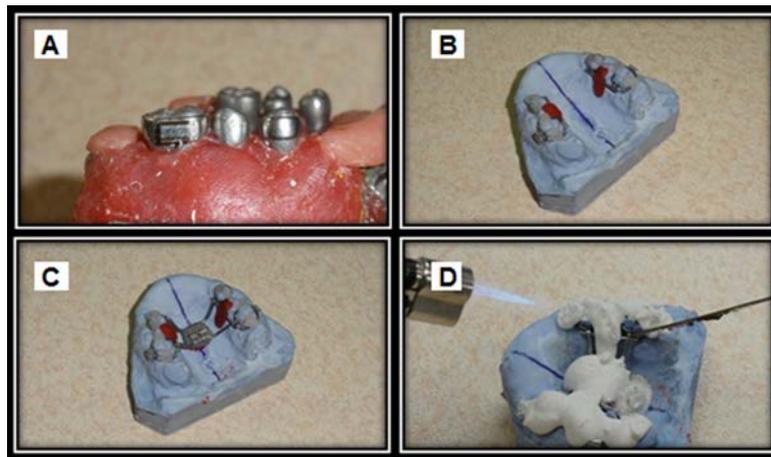
#### B. Fabrication of Palatal Expanders

An impression was taken using alginate impression material (Major, Italy) with preformed bands (Dentaurum, Germany) were fitted on 1<sup>st</sup> premolars and 1<sup>st</sup> molars of typodont bilaterally for the hyrax expanders; while for the Quad-Helix and the W-Arch expanders, only 1<sup>st</sup> molars were banded. Then the impression was poured with dental stone after ensuring that bands were in their place in the impression. On the cast model, the fitted bands were checked that were brought down to the height of marginal ridges of

the teeth and then fixed with soft wax. <sup>(15)</sup> (Figure 2: A)

For the Hyrax appliances, the premolars and molars bands were joined on the palatal side with a piece of 1mm stainless steel wire. This wire was contoured from palatal surface of first molars to first premolars. <sup>(16)</sup> (Figure 2: B) Legs of the Hyrax screw (Dentaurum, Germany) were bent to fit the bands. The Hyrax

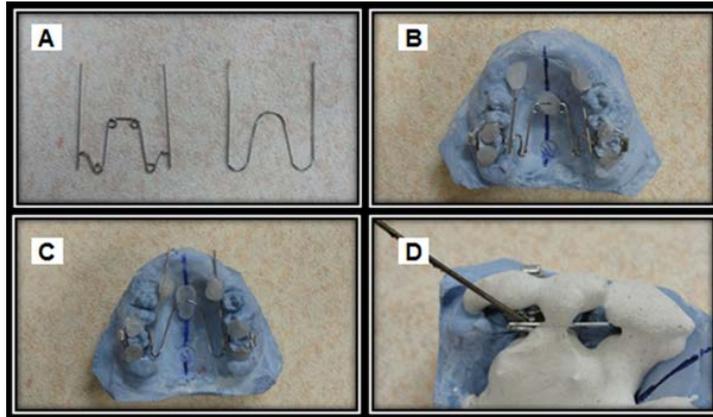
screw was positioned at the midline <sup>(14)</sup> (Figure 2: C). According to the manufacturer's instructions (Dentaurum, Germany), screw should be float freely 1-2mm above the simulated palate roof. It should be ensured that the occlusal level is parallel. After that bands, hyrax screw and the metal bar were hold in position by plaster. All these components were soldered and then polished (Figure 2: D).



**Figure (2):** (A) Preformed bands are fitted on 1<sup>st</sup> bicuspid and 1<sup>st</sup> molar of typodont, (B) Joining the bands from palatal side with 1 mm SS wire and fixed with sticky wax, (C) Placing the Hyrax screw at the midline, (D) Holding the Hyrax components in position with plaster followed by soldering.

For the Quad-Helix and the W-Arch appliances, a prefabricated Quad-Helix of 0.9mm (Dentaurum, Germany) was used while the W-Arch was manually made out of 0.9mm round stainless wire. The W-Arch expander had the same dimensions as the Quad-Helix expander <sup>(17)</sup> (Figure 3: A). These expanders were placed at the middle of the cast. <sup>(9)</sup> The free wire was ended adjacent to the posterior loops for

the W-Arch appliances and posterior helices for the Quad-Helix appliances. The outer arms were rested against the palatal surfaces of the premolars and were soldered to the palatal aspect of the 1<sup>st</sup> molar bands <sup>(18)</sup>. (Figure 3: B and C) Then bands, the Quad-Helix and the W-Arch main-frames were hold in position by plaster followed by soldering and polishing these components (Figure 3: D).



**Figure (3):** (A) The W-Arch fabricated as the same dimension of the Quad-Helix, (B) Positioning the Quad-Helix at the middle of the cast and adaptation, (C) Positioning the W-Arch at the middle of the cast and adaptation, (D) Holding the Quad-Helix and W-Arch components in position with plaster followed by soldering.

### C. Preparation of Laboratorial Environments

Specially designed wood table of 30×21cm in dimension to which a metal base of typodont articulator was attached vertically at 90° using a protractor. A standard distance of 15cm between the digital camera and the base of typodont was maintained. A metallic ruler was fixed

to the wood table. This ruler was placed perpendicular using a protractor to the wood table and in the same level with the occlusal plane of typodont teeth (Figure 4). This ruler was used for the standardization of pre and postoperative images of the occlusal view which were analyzed by Autodesk AutoCAD<sup>®</sup> software.



**Figure (4):** Wood table to which a metal base of typodont articulator and a ruler were attached to it.

### D. Standardization of the Tools

After each experiment, the typodont teeth were repositioned to their original position before expansion by immersing the typodont in the water bath, and then the acrylic bite plane was seated on the typodont. The premolars and first molars teeth were brought to their positions by

seating the end of the clamping tweezers in a groove made on the buccal surface of these teeth and driving the tooth to its position against the acrylic bite plane (Figure 5). Before starting expansion, the measurements were checked using digital vernia.



**Figure (5):** Reposition the teeth with the acrylic bite plane using clamping tweezers for driving the tooth to its position.

For maxillary width measurements; the distance between the palatal cusp tips of 1<sup>st</sup> and 2<sup>nd</sup> premolars bilaterally was  $30.6\text{mm}\pm 0.1$  and  $34.3\text{mm}\pm 0.1$  respectively. The distance between the mesiopalatal cusps tips of 1<sup>st</sup> molars bilaterally was  $37.6\text{mm}\pm 0.1$ .

For anteroposterior measurements; the distance between the buccal cusp tips of 1<sup>st</sup> and 2<sup>nd</sup> premolars on the right and left sides was  $7.3\text{mm}\pm 0.1$  and  $7\text{mm}\pm 0.1$  respectively. The distance between the buccal and mesiobuccal cusp tips of 2<sup>nd</sup> premolar and 1<sup>st</sup> molar on the right and left sides was  $5.6\text{mm}\pm 0.1$  and  $6\text{mm}\pm 0.1$  respectively.

For vertical measurements; the vertical height between the base of typodont and buccal cusp tips of premolars and mesiobuccal cusp tips of 1<sup>st</sup> molar was  $53\text{mm}\pm 0.1$  for both right and left sides.

Water baths have controlled temperature of about  $54^{\circ}\text{C}\pm 2$ . Typodont was immersed in the digital water bath for about five minutes. Then the Typodont was immersed in a cool water of about  $5^{\circ}\text{-}10^{\circ}\text{C}$  for five minutes<sup>(19)</sup>.

#### E. Activation of Expanders

The Hyrax appliance was expanded 2mm by activating the screw, using the

blue safety key, 8 quarter-turns. Each one quarter-turn brought about 0.25mm expansion<sup>(20)</sup>. Both the Quad-Helix and the W-Arch appliances were expanded 2mm; drawing a shape of the bands and arms of the appliance before activation helps to keep the shape of expanded appliance<sup>(21)</sup>.

#### Pre and Postoperative Image Analysis

Pre and postoperative images for all trials were analyzed by Autodesk AutoCAD<sup>®</sup> software. The images from occlusal view were scaled in a manner that the distance of 10mm on the image was equal to a distance of 10mm on the ruler. So, the linear measurements on the image were equal to the real measurements in the same plane. Digital images analyses were made by drawing three lines (Figure 6):

- 1- **Maxillary inter-first premolar line** was drawn between the palatal cusp tips of the maxillary 1<sup>st</sup> premolars.
- 2- **Maxillary inter-second premolar line** was drawn between the palatal cusp tips of the maxillary 2<sup>nd</sup> premolars.
- 3- **Maxillary inter-molar line** was drawn between the mesiopalatal cusp tips of the maxillary 1<sup>st</sup> molars.



**Figure (6):** Image analysis by Autodesk AutoCAD© software after drawing three lines: (A) maxillary inter-first premolar line; (B) maxillary inter-second premolar line and (C) maxillary inter-molar line

### Statistical Analysis

Statistical analysis was performed using the (SPSS Version 11.5) statistical program. The data were tested for their normal distribution by using the Shapiro-Wilks test. According to the results of this test, the data achieved were analyzed using the one way ANOVA followed by Duncan's multiple range tests to locate the significant differences among means of these 3 groups.

### RESULTS

Descriptive statistics that includes mean, standard deviation, minimum and maximum value of maxillary inter-1<sup>st</sup> premolar, inter-2<sup>nd</sup> premolar and inter-1<sup>st</sup> molar width changes measured for Hyrax, Quad-Helix and W-Arch groups are listed in Table (1).

The maxillary inter-1<sup>st</sup> premolar width changes were  $1.41 \pm 0.23$ mm for the Hyrax group,  $0.93 \pm 0.33$ mm for the Quad-Helix group and  $0.92 \pm 0.38$ mm for the W-Arch

group. The Hyrax group revealed the highest value with a significant difference from the Quad-Helix and W-Arch groups. There was no significant difference between the remaining two groups ( $P \leq 0.05$ ).

The maxillary inter-2<sup>nd</sup> premolars width change were  $1.54 \pm 0.18$  mm for the Hyrax group,  $0.64 \pm 0.44$ mm for the Quad-Helix group and  $0.51 \pm 0.24$ mm for the W-Arch group. The Hyrax group displayed the highest value with a significant difference from the Quad-Helix and W-Arch groups. There was no significant difference between the remaining two groups ( $P \leq 0.05$ ).

The maxillary inter-1<sup>st</sup> molar width change were  $0.96 \pm 0.22$ mm for the Hyrax group,  $0.52 \pm 0.39$ mm for the Quad-Helix group and  $0.43 \pm 0.27$ mm for the W-Arch group. The Hyrax group showed the highest value with a significant difference from the Quad-Helix and W-Arch groups. There was no significant difference between the remaining two groups ( $P \leq 0.05$ ).

**Table (1):** Descriptive statistic of the parameters measured in the study.

Group	Variable	Mean	±Std. Dev.	Minimum	Maximum
<b>Hyrax</b>	Inter-maxillary 1st premolar width changes (mm)	1.41	±0.23	1.01	1.69
	Inter-maxillary 2nd premolars width change (mm)	1.54	±0.18	1.21	1.73
	Inter-maxillary 1st molar width change (mm)	0.96	±0.22	0.50	1.22
<b>Quad-Helix</b>	Inter-maxillary 1st premolar width changes (mm)	0.93	±0.33	0.47	1.40
	Inter-maxillary 2nd premolars width change (mm)	0.64	±0.44	0.10	1.43
	Inter-maxillary 1st molar width change (mm)	0.52	±0.39	0.10	1.25
<b>W-Arch</b>	Inter-maxillary 1st premolar width changes (mm)	0.92	±0.38	0.20	1.41
	Inter-maxillary 2nd premolars width change (mm)	0.51	±0.24	0.17	0.80
	Inter-maxillary 1st molar width change (mm)	0.43	±0.27	0.10	0.80

(mm) = millimeter

**Table (2):** Comparison differences among Hyrax, Quad-helix and W-Arch.

Variable	Group	Mean	±Std. Dev.	F-Value	P-value	Duncan's Group
<b>Inter-maxillary 1<sup>st</sup> premolar width change (mm)</b>	Hyrax	1.41	0.23	7.356	0.003*	B
	Quad-Helix	0.93	0.33			A
	W-Arch	0.92	0.38			A
<b>Inter-maxillary 2<sup>nd</sup> premolar width change (mm)</b>	Hyrax	1.54	0.18	32.575	0.000*	B
	Quad-Helix	0.64	0.44			A
	W-Arch	0.51	0.24			A
<b>Inter-maxillary 1<sup>st</sup> molar width change (mm)</b>	Hyrax	0.96	0.22	8.499	0.001*	B
	Quad-Helix	0.52	0.39			A
	W-Arch	0.43	0.27			A

\* P ≤ 0.05; (mm) = millimeter

## DISCUSSION

The outcomes of the present study showed that there was a significant difference regarding the rate of maxillary inter-1<sup>st</sup> premolars width change, (1stPWC), the rate of maxillary inter-2<sup>nd</sup> premolars width change, (2ndPWC) and the rate of maxillary inter-1<sup>st</sup> molars width change, (1stMWC), between the Hyrax expander and the other two expanders, while there was no significant difference between the

Quad-Helix and the W-Arch expanders regarding those changes.

This may be attributed to the possibility that a larger force is applied by the Hyrax expander on the premolars and molars teeth resulting in more expansion rate. An activation of the Hyrax appliance in each quarter turn, at least 900g of force is applied to the teeth<sup>(22)</sup>; while the Quad-Helix produces forces between 180g and 667g, depending on the material used, and the

length and the size of the wire.<sup>(23)</sup> For the W-Arch expanders, activation of W-Arch appliances constructed from 0.036" diameter arch wires produced forces approximately of 383.4g.<sup>(17)</sup> So, larger forces of expansion applied by the Hyrax appliance is contribute to the design of the Hyrax which allow delivery of large forces than both the Quad-Helix and the W-Ach appliances.

When examining arch width changes, we observed that the Hyrax appliance increased the 1stPWC at a range of 1.41mm, while the Quad-Helix and the W-Arch appliances resulted in an increase at 1stPWC at a rate of 0.93mm and 0.92mm respectively. The results of the Quad-Helix expander of the present study are close to a study by Bjerklin<sup>(24)</sup>, who saw an increase of 1.3 mm in the 1stPWC; and are less than other studies which reported an increase of 1stPWC range from 3.1mm to 5.8mm.<sup>(25, 26)</sup>

The Hyrax appliance increased the 2ndPWC at a range of 1.54mm, while the Quad-Helix and W-Arch appliances resulted in an increase in 2ndPWC at a rate of 0.64mm and 0.51mm respectively. In a study by Li and Lin<sup>(26)</sup>, the 2ndPWC increased at a mean of 4.4mm.

The Hyrax expander in this study increased the 1stMWC at a mean of 0.96mm which is less than reported by other studies which accomplished intermolar expansion more than 4mm.<sup>(27, 28)</sup> The W-Arch and the Quad-Helix appliances increased the 1stMWC at a mean of 0.43mm and 0.52mm respectively. Some studies achieved an increase of more than 3mm in the 1<sup>st</sup> MWC<sup>(24, 26)</sup>; while others achieved more than 4mm with the Quad-Helix appliances.<sup>(28, 29, 30)</sup>

The findings of the present study disagree with Hyunh *et al.*<sup>(27)</sup> and Wong *et al.*<sup>(28)</sup>, who stated that both the Hyrax and Quad-Helix appliances showed similar amount of intermolar expansion after SME. A likely explanation is that SME has carried out in young patients at pre-adolescent, so suture has little interdigitation and opens easily under light forces regardless of expander type.<sup>(27)</sup>

All mentioned studies have carried out clinically on patients after SME. This difference between the present study and oth-

er researches was contributed to the fact that the present study is conducted on tyodont and after an activation of 2mm only, while all mentioned studies are conducted clinically on patients; and until complete expansion and treatment of posterior crossbite which require an activation of expanders for more than 2mm.

## CONCLUSION

According to the present study, the Hyrax expander increases the intermaxillary premolars and molars width more reliably than the Quad-Helix and the W-Arch expanders. Both Quad-Helix and W-Arch expanders increases the inter premolars and molars width at similar rates.

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