

doi:10.3969/j.issn.2095-4344.2013.28.013 [http://www.crter.org]

Wang F, Lu HX, Lin SS. Long-term effect of quad helix expansion of dental arch. *Zhongguo Zuzhi Gongcheng Yanjiu*. 2013;17(28): 5177-5183.

Long-term effect of quad helix expansion of dental arch*☆

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Abstract

BACKGROUND: Rapid expansion of the dental arch is an effective way to rapidly expanse the jaw. Compared with rapid expansion, the slow expansion has higher stability and less recurrence, but the reports on the long-term stability of quad helix expansion are rare.

OBJECTIVE: To retrospectively analyze the clinical effect of quad helix expansion in orthodontics.

METHODS: Twenty-two subjects with dental arch stenosis in mixed dentition and early permanent dentition who experienced an expansion of at least 3 mm with quad helix appliance were selected for this study. Plaster dental casts and posteroanterior radiographs were evaluated at the beginning of the treatment (T1), at the completion of phase I quad helix expansion or full treatment (T2), and approximately 2 years following the completion of treatment (T3). The distance between two first molars was measured on the model. J point was drawn on the posteroanterior radiograph in order to measure the distance between the bilateral base bones and the molar inclination, as well as to evaluate the corrective and orthopedic effects of dental arch expansion.

RESULTS AND CONCLUSION: Compared with that before expansion, the first permanent molar inclination and the distance between base bones on two sides were significant increased after quad helix expansion; there were no significant differences in the distance between two first permanent molars, first permanent molar inclination and the distance between bilateral base bones on two sides when compared after quad helix expansion and after 2-year follow-up ($P > 0.05$). The results indicate that the long-term effect of quad helix expansion is stable with orthopedic effect.

Key Words: tissue construction; oral tissue construction; quad helix; maxillary arch expansion; orthodontics; arch width; dental arch stenosis; dental arch expansion; first permanent molar; National Natural Science Foundation of China

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Supported by: National
Natural Science Foundation
of China, No. 81070837*

Received: 2012-02-06
Accepted: 2012-07-24
(N20111004001/YJ · C)

INTRODUCTION

Treatment of narrow and collapsed maxillary arches by expansion has been accomplished through many different modalities for more than a century. Maxillary expansion can be achieved through orthodontic or surgery^[1-4]. The objective of rapid palatal expansion is to quickly produce transverse separation of the maxilla by expanding the midpalatal suture and apical base while minimizing concomitant orthodontic positive inclination or buccal tipping tooth movements^[5-11]. However, slower expansion techniques have been associated with greater adaptation of sutures during expansion, resulting in greater stability and less relapse potential than with rapid expansion techniques^[12-14].

The purpose of this study was to quantify, retrospectively, orthopedic and orthodontic changes resulting from quadhelix expansion therapy using the records at the beginning of the treatment (T1), at the completion of phase I quad helix expansion or full treatment (T2), and approximately 2 years following the completion of treatment (T3).

SUBJECTS AND METHODS

Design

A retrospectively analysis.

Time and setting

The experiment was performed at the Department of Stomatology, Navy General Hospital of PLA from July 2007 to July 2011.

Subjects

The patients with dental arch stenosis in mixed dentition and early permanent dentition stages were selected from the Department of Stomatology, Navy General Hospital. Diagnostic criteria: The dental arch stenosis in mixed and early permanent dentition stages was diagnosed according to literature^[15].

Inclusion criteria: (1) Conformed to the diagnostic criteria. (2) The arch was expanded by quad helix appliance for 3 mm at least. (3) The experiment obtained the informed consent of patients and their caregivers.

Exclusion criteria: (1) Patients did not complete the 2-year follow-up. (2) Patients did not obtain the posteroanterior radiographs at the beginning of the treatment (T1), at the completion of phase I quad helix expansion or full treatment (T2), and approximately 2 years following the completion of treatment (T3).

Finally, 22 patients with dental arch stenosis in mixed dentition and early permanent dentition stages were included for this study. The average age of the patients was 11.4 years (ranged 8.8–13.5 years).

Methods

Measurement of intermolar width and maxillary width with Boley gauge

The maxillary first molar intermolar width and maxillary width from each group were measured. Measurements were made with a Boley gauge (FEI Company) to the nearest 0.5 mm by the principal investigator.

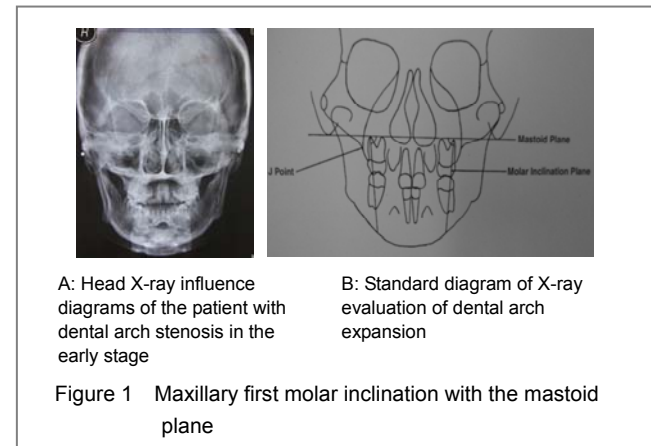
Plaster dental casts were used to evaluate the transverse changes

The casts were used to evaluate the transverse changes from T1 to T2, from T2 to T3, and from T1 to T3. The time from T1 to T2 accounted for short-term stability evaluation and the time from T2 to T3 accounted for long-term stability evaluation. The T3 record was analyzed and evaluated for long-term maxillary transverse dental stability or relapse due to simple alveolar bending. Measurements included maxillary intermolar width from central fossa to central fossa of the first molars.

X-ray film evaluation of the skeleton after dental arch expansion

With the frontal cephalograph tracing (Figure 1), the best fit of the maxillary first molar template was used with the most buccal aspect of the maxillary first molar and the apex of its root. A line was constructed through the apex of the buccal root and buccal cusp tip of the template tracing. The angle formed from this line and a horizontal line constructed from the most inferior point of the mastoid processes was measured. It suggested that this angular measurement (inclination) gave an

idea as to how possible dental buccal tipping movement or alveolar change occurred (comparing between T1, T2 and T3). Maxillary skeletal transverse changes were measured from left to right J point on the frontal cephalogram at T1, T2, and T3.



Main outcome measures

The orthodontic effect of dental arch expansion was evaluated.

Statistical analysis

SPSS 11.0 (SPSS, Chicago, IL, USA) was applied for statistic analysis. Statistical methods involved collecting response vectors for each variable, consisting of two angles (right and left) for each maxillary molar on each frontal tracing, and maxillary intermolar distance for T1, T2 and T3. A two-factor mixed effect analysis of variance model was performed in order to determine significant changes that occurred between stages in time. A value of $P < 0.05$ was considered statistically significant.

RESULTS

Data analysis and clinical data of the subjects

All the 22 patients were included in the analysis. A repeated measures analysis of variance model showed the interaction of time, age, duration of quad helix treatment, the interaction of time and duration had no statistically significant effect on intermolar distance ($P > 0.05$), but the duration (T1, T2, T3) had a highly significant effect on intermolar distance ($P < 0.05$) (Table 1).

The increasing of intermolar width of the dental arch stenosis patients after dental arch expansion

The result showed that the duration (T1, T2, T3) had a significant effect on intermolar distance ($P < 0.05$). The two sample *t*-test showed there was statistically significant increasing in intermolar distance from T1 to T2 ($P < 0.05$), there was no significant difference in intermolar distance from T2 to T3 ($P > 0.05$), and there

was a statistically significant increasing in intermolar distance from T1 to T3 ($P < 0.05$, Table 2).

Table 1 Clinical data of the patients with dental arch stenosis

Subject	Gender	Duration of quad helix expansion (mon)	Age at T1 (yr)	Age at T2 (yr)	Age at T3 (yr)
1	Male	3.5	11.3	13.7	17.2
2	Male	2.5	12.1	15.2	17.8
3	Female	2.0	13.3	14.8	17.1
4	Female	5.0	12.5	14.8	16.8
5	Female	10.0	9.7	14.2	16.1
6	Female	7.5	8.8	13.7	15.2
7	Female	8.0	9.2	9.8	13.7
8	Male	7.5	8.8	11.4	13.3
9	Female	7.5	9.4	12.8	14.7
10	Male	4.0	8.8	11.7	13.7
11	Male	3.0	12.4	16.1	17.9
12	Female	5.0	9.1	12.4	15.1
13	Female	4.0	12.2	14.8	17.2
14	Female	5.0	13.5	15.0	17.7
15	Female	11.0	11.7	14.4	17.0
16	Female	5.5	10.7	14.8	17.1
17	Male	6.0	10.1	10.6	13.2
18	Male	7.0	8.8	9.5	12.6
19	Female	3.0	9.9	11.9	13.8
20	Male	5.0	10.2	12.2	14.7
21	Male	3.5	11.5	13.5	16.1
22	Male	4.5	11.4	12.2	14.2

Subject	Gender	Intermolar distance at T1 (mm)	Intermolar distance at T2 (mm)	Intermolar distance at T3 (mm)
1	Male	36.0	42.5	42.5
2	Male	48.0	51.0	51.0
3	Female	44.5	48.5	45.5
4	Female	36.0	42.0	41.5
5	Female	42.5	47.0	46.0
6	Female	45.0	49.0	48.0
7	Female	43.0	47.0	44.0
8	Male	42.0	45.0	42.0
9	Female	42.0	45.0	48.0
10	Male	43.0	47.0	47.5
11	Male	44.5	48.0	46.5
12	Female	42.0	48.0	44.5
13	Female	38.0	41.0	41.0
14	Female	47.0	50.0	49.5
15	Female	44.5	48.5	48.0
16	Female	42.0	47.0	47.0
17	Male	42.0	46.0	45.0
18	Male	43.0	46.0	44.5
19	Female	42.5	46.0	44.0
20	Male	45.0	48.0	48.0
21	Male	42.5	45.5	46.5
22	Male	41.0	47.0	45.0

T1: Before quad helix expansion; T2: At the completion of phase I quad helix expansion or full treatment; T3: Approximately 2 years following the completion of treatment. There were no significant differences in the age and duration of treatment between patients, but intermolar distance at T1, T2 and T3 was different.

Table 2 The maxillary first molar intermolar width of dental arch stenosis patients at different time points ($n=22$)

Time	Maxillary first molar intermolar width ($\bar{x} \pm s$, mm)	CV (%)
T1	42.57 \pm 3.03 ^{ab}	7.12
T2	46.62 \pm 2.52	5.41
T3	45.74 \pm 2.67	5.48

T1: Before quad helix expansion; T2: At the completion of phase I quad helix expansion or full treatment; T3: Approximately 2 years following the completion of treatment. ^a $P < 0.05$, vs. T2, ^b $P < 0.05$, vs. T3. The maxillary first molar intermolar width was increased with the prolonging of treatment. Time: time of radiographic records; CV=confident of variation (%)=standard deviation mean maxillary first molar intermolar width \times 100%.

Decreasing of maxillary first molar inclination of the dental arch stenosis patients after expansion

For results of inclination measurement (Table 3), a general linear model showed that duration had a statistically significant effect on angle ($P < 0.05$). The two sample t -test showed that there was a significant decreasing in inclination from T1 to T2 ($P < 0.05$). There was no significant difference in inclination from T2 to T3 ($P > 0.05$). However, there was a significant decreasing in inclination from T1 to T3 ($P < 0.05$). Thus, the results showed that the maxillary first molar inclinations from T1 to T2 were decreased, the curve of Wilson was diminished with treatment. However, the intermolar distances were increased from T1 to T2. There was no significant decrease in maxillary first inclination or intermolar distance between T2 to T3.

Table 3 The maxillary first molar inclination of the dental arch stenosis patients at different time points ($n=22$)

Time	Maxillary first molar inclination ($\bar{x} \pm s$, °)	CV (%)
T1	93.83 \pm 5.65 ^{ab}	6.02
T2	91.90 \pm 4.59	4.99
T3	91.68 \pm 4.93	5.38

T1: Before quad helix expansion; T2: At the completion of phase I quad helix expansion or full treatment; T3: Approximately 2 years following the completion of treatment. ^a $P < 0.05$, vs. T2, ^b $P < 0.05$, vs. T3. The maxillary first molar inclination was decreased from T1 to T2, while there was no significant decreasing from T2 to T3. Time: time of radiographic records; CV=confident of variation (%)=standard deviation/mean maxillary first molar inclination in degrees \times 100%.

Increasing of distance between base bones on two sides of dental arch stenosis patients after expansion

Evaluation of J point measurements (Table 4) using the Wilcoxon Rank Test at the significance level of $\alpha=0.5$

indicated that there was a statistically significant increasing from T1 to T2 ($P < 0.05$) and from T1 to T3 ($P < 0.05$). There was no statistically significant change from T2 to T3 ($P > 0.05$).

Table 4 Distance between base bones on two sides of the dental arch stenosis patients at different treatment time points ($n=22$)

Item	J point at T1	J point at T2	J point at T3
Mean (mm)	60.00	62.79	63.50
Median (mm)	59.90	58.20	59.20
SD (mm)	2.67	3.66	3.29
Variance	7.13	13.39	10.79
CV (%)	4.45	5.83	5.17
Range (mm)	8.70	11.10	10.30
Minimum (mm)	56.00	58.20	59.20
Maximum (mm)	64.70	69.30	69.50

T1: Before quad helix expansion; T2: At the completion of phase I quad helix expansion or full treatment; T3: Approximately 2 years following the completion of treatment. CV=coefficient of variation (%)=standard deviation/mean maxillary first molar inclination in degrees $\times 100\%$. SD: standard deviation.

DISCUSSION

This study provided the opportunity to quantify skeletal (using J point) as well as maxillary intermolar expansion (using study models) by the quad helix appliance for both short- and long-term stability. It also provided an evaluation of molar inclination as a direct result of using the quad helix. These factors are important considerations for the practitioner in determining treatment options and outcomes.

Some studies evaluated the quad helix and removable appliances in children and found that both methods can achieved sufficient expansion^[16-21]. In the removable appliance group, the expansion was mainly due to buccal tipping, while in the quad helix group, the expansion was primarily due to buccal translation. Somewhat, greater basal expansion can be achieved in the quad helix group as indicated by increased maxillary intermolar width. McNally *et al*^[22] also showed the advantages of the quad helix in the treatment of a posterior crossbite in the mixed dentition. Buccal tipping of the maxillary teeth occurs initially during expansion. However, in the latter phase of expansion, increasing in linear arch width is mainly due to bodily translation rather than an increasing rate of buccal tipping of posterior teeth. With slow maxillary expansion, both dental and skeletal expansion is slightly greater posteriorly than anteriorly. This pattern of expansion contrasts that rapid palatal expansion where

more separation occurs anteriorly than posteriorly^[23-28]. The mean maxillary molar inclination for this sample decreases from T1 to T2. At the same time, intermolar width is increased. The decreasing in inclination may be due to several factors. The time of quad helix removal is not the same time as the T2 record, which were taken at the end of either full or phase I treatment. Other treatment mechanics may have helped with molar up-righting from the time of quad helix removal to T2. The effects of molar rotation on molar angle/inclination may have also played a role in the decreasing of measured molar inclination. From T2 to T3 (long-term), there is no significant difference in either angular measurements (inclination) or intermolar width, taking into account the muscular forces produced by the cheeks and tongue. The magnitude of midpalatal suture separation with slow maxillary expansion is comparable to that in rapid palatal expansion^[29-31]. Slow maxillary expansion may result in early postexpansion skeletal stability. Tooth movement relapse after maxillary expansion, autonomous postexpansion lingual tipping of molars, is caused by the attached soft-tissue and/or surrounding perioral musculature^[32-36]. The significant increasing in maxillary width detected using J point measurement from T1 to T2 and T2 to T3 indicates a probable orthopedic change in the maxilla. Although, there was a slight increasing in maxillary width from T2 to T3, the increasing was not statistically significant. This slight increase may be the result of other treatment mechanics during phase II treatment, or slight transverse growth of the maxilla in the younger subjects of the study.

Because the mean age of 11.4 is pre-adolescent, follow-up on late adolescents and adults would be appropriate. The degree of orthopedic change during slow maxillary expansion is generally thought to be inversely related to patient age^[37-40]. In an adult patient, the quad helix does not produce sufficient force to create an orthopedic effect on the maxilla. It is also important to realize that other treatment mechanics, such as arch wire, have an effect on maxillary intermolar expansion. Retention may have contributed to prevention of relapse. However, it is difficult to determine the compliance of retainer wear after T2 and between phase I and phase II for younger subjects.

The findings of this study contribute to our understanding in the correction of transverse and arch-length discrepancies via the quad helix appliance for this age group. A major advantage of the quad helix is more physiologic adaptation to expansion, which may result in less sutural relapse and a more stable correction if the

midpalatal suture was actually separated^[41-42]. Due to the small sample size of this study, a clear understanding would be gained with a larger sample size and by taking maxillary occlusal radiographs just prior to quad helix placement and taking them just after the quad helix would be removed to evaluate a possible sutural change. Long-term orthopedic expansion was demonstrated by the significant increase in maxillary width from T1 to T2 and T1 to T3, using the difference in millimeters from left to right J points on the frontal cephalogram tracings. Although the mean maxillary first molar inclination decreased from T1 to T2, the intermolar width was increased, with no significant angular change from T2 to T3. These findings imply a possible orthopedic change at the suture or remodeling of the alveolus in this study. But our research was limited to using two-dimensional X-rays for data acquisition or model analysis, which only allows dental measurements. The increased accuracy of measurements using cone beam computed tomography comes from the sub-millimeter isotropic voxel resolution, which ranges from 0.4 mm down to 0.125 mm with some systems^[43-44]. Computed tomography analysis of RME effects have proven to give better quantity and exactness of diagnostic parameters measured, and may soon become routine analysis for patients undergoing such treatment.

The use of cone beam computed tomography will allow for new, more reliable levels of measurements as witnessed by high intraclass correlation coefficient values^[45]. The ability to obtain maxillary sinus width measurements and to quantify finite changes in alveolar bending at various points on the sagittal plan were unavailable prior to three-dimensional imaging. The new information gained with cone beam computed tomography will serve to improve three-dimensional modeling and finite element analysis algorithms, benefiting orthodontics by enhancing the tools and knowledge we use to diagnose cases and implement treatment modalities.

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四圈簧扩大牙弓的长期效果*☆

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文章亮点:

1 实验从长期稳定性角度着手, 随访矫正完成 2 年的病例, 时间跨度大, 其结果填补了四圈簧扩弓矫治长期稳定性的空白。

2 结果显示四圈簧扩弓治疗后 2 年后, 患者两侧第一恒磨牙间距离、第一恒磨牙倾斜度和两侧基骨间距离为发生明显改变。

关键词:

组织构建; 口腔组织构建; 四圈簧; 上颌扩弓; 正畸; 牙弓宽度; 牙弓狭窄; 扩大牙弓; 第一恒磨牙; 国家自然科学基金

摘要

背景: 快速扩大牙弓是快速扩大颌骨的有效方法, 而与快速扩展相比, 缓慢扩展稳定性更高, 复发更少, 但四圈簧扩弓的长期稳定性少见报道。

目的: 回顾性分析正畸临床中四圈簧扩大牙弓的临床效果。

方法: 混合牙列期及恒牙列早期牙弓狭窄患者 22 例使用四圈簧扩大牙弓至少 3 mm, 在扩大牙弓之前(T1 期)、I 期四圈簧扩弓治疗完成或整个治疗结束(T2 期)及治疗完成后 2 年(T3 期)分别制取牙齿石膏研究模型并摄取头颅后前位片, 在模型上测量两侧第一恒磨牙之间距离, 在后前位片上描点(J 点)测量两侧基骨间距离及磨牙倾斜度, 评价牙弓扩大的矫正及矫形效果。

结果与结论: 与扩弓前相比, 四圈簧扩弓治疗后患者第一恒磨牙倾斜度和两侧基骨间距离逐渐减小; 而四圈簧扩弓治疗后相比, 随访 2 年时, 患者两侧第一恒磨牙间距离、第一恒磨牙倾斜度和两侧基骨间距离的差异无显著性意义($P > 0.05$), 提示四圈簧扩大牙弓的长期效果是稳定的, 并有矫形效果。

基金资助: 课题受国家自然科学基金(81070837)资助。

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伦理要求: 实验获得解放军海军总医院医学伦理学委员会的批准。

学术术语: 扩大牙弓一是矫治牙列拥挤的主要方法之一, 通过矫治器将牙弓的宽度或长度扩大, 在牙弓上获得一定间隙, 从而使拥挤错位的牙齿排列整齐。扩大上牙弓前段长度, 可以矫治地包天, 扩大上牙弓后段宽度, 可以使下牙弓向前调整, 使上下磨牙间的关系异常得到矫正; 下牙弓的长、宽扩大可矫治上下牙弓间关系的不协调。

作者声明: 文章为原创作品, 数据准确, 内容不涉及泄密, 无一稿两投, 无抄袭, 无内容剽窃, 无作者署名争议, 无与他人课题以及专利技术的争执, 内容真实, 文责自负。

中图分类号: R318 文献标识码: A

文章编号: 2095-4344(2013)28-05177-07

王峰, 陆怀秀, 林松杉. 四圈簧扩大牙弓的长期效果[J]. 中国组织工程研究, 2013, 17(28):5177-5183.

(Edited by Zheng CS, Song JL/Chen X/Wang L)