ORIGINAL ARTICLE

Dentofacial changes after anterior crossbite correction using a lingual arch with finger springs

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KEYWORDS
anterior crossbite; cephalometric; tooth movement

Abstract  Background/purpose: Anterior crossbite correction is common in orthodontic treatment; however, few studies have discussed the change with cephalometric measurements. The purpose of this study was to evaluate the dentofacial changes in anterior crossbite correction by using an upper lingual arch with finger springs.

Materials and methods: This retrospective study included 30 patients (13 female and 17 male). According to the number of crossbite teeth, the patients were divided into three groups. We used paired t test, Kruskal–Wallis test, Mann–Whitney U test, and multiple regression analysis to perform statistical analysis.

Results: According to overall treatment changes, the dental changes included overjet increase, overbite decrease, upper incisor proclination, lower incisor retroclination and intrusion, upper molar distal tipping with extrusion, and lower molar intrusion. These dental changes resulted in clockwise mandibular rotation and lip position change. Anterior crossbite correction did not require increasing bite appliances. According to multiple regression analysis, the change in overjet was associated with the position of the upper and lower incisor crown tips. The mean rate of upper incisor movement in the horizontal direction was 2.5 mm/mo. The treatment duration exhibited no significant difference among the three groups.

Conclusion: Lingual arch with finger springs was effective in anterior crossbite correction regardless of the number of crossbite teeth.

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Introduction

Most previous studies have introduced treatment methods for anterior crossbite only through case presentations concerning devices such as removable appliances, bonded resin composite slopes, and hexa helix, but quantitative research about tooth movement is rarely reported. Mershon first used the lingual arch in 1908. In the Mershon method, appliances were used at intervals throughout the growth period of a patient, producing changes as the child grows and develops, with frequent periods of rest during which the appliances are removed to allow natural adaptation of the teeth to their new positions. The lingual arch springs were soldered and bent for different uses. The author used the appliance for many types of orthodontic treatment, such as arch expansion, rotation correction, labial tooth movement, and tooth distalization. The lingual arch with finger springs (LAFS) was widely used for many years, but no relevant reports about the effect and efficiency of the appliance and tooth movement have been published. The objectives of this study were: (1) to introduce LAFS, which was used for correcting anterior crossbite; (2) to evaluate the changes in and efficiency of anterior crossbite correction by using cephalometric analysis; and (3) to identify the factors associated with changes in crossbite correction.

Material and methods

Lingual arch with finger springs

Mershon first used the lingual arch in 1908. The lingual arch springs were soldered and bent for different uses, such as arch expansion, rotation correction, labial tooth movement, and tooth distalization. In this study, a Mershon lingual arch was modified and used (Figure 1). This appliance was fixed and cemented on the upper first molars.

Patients

All samples were collected from Taipei Medical University Hospital, Taipei, Taiwan during 2011–2013. Ethical approval was obtained from the Institutional Review Board of Taipei Medical University. The inclusion criteria were as follows: (1) one or more incisors in crossbite; (2) no previous orthodontic treatment; (3) anterior crossbite corrected by using an LAFS; and (4) complete pretreatment and posttreatment orthodontic records. The exclusion criteria were: incomplete of treatment records and patients did not return for checkup on time. Initially, 52 patients were selected; however, 22 patients were excluded because of incomplete data or patient factors. Of the 22 patients, 19 did not have posttreatment cephalometric radiographs, two did not have initial cephalometric radiographs, and one did not return for treatment on time. According to the number of crossbite teeth, the patients were divided into three groups: Group 1 comprised eight patients with one tooth in crossbite; Group 2 comprised nine patients with two teeth in crossbite; and Group 3 comprised six patients with three teeth in crossbite and seven patients with four teeth in crossbite. The patients in Group 3 all had functional shift with edge to edge incisor relationship.

All correction appliances, namely, LAFS, were constructed by one of the authors. In our clinic, after the appliances were delivered, the patients were examined and the appliances were adjusted every 3 weeks or 4...
weeks. Once the crossbites were corrected, intraoral photos and cephalometric films were acquired. Decisions to continue full-mouth orthodontic treatment or follow-up varied. For patients with permanent dentition, after crossbite correction, full-mouth orthodontic treatment was continued (Figure 2). Patients with mixed dentition were recalled every 3–6 months, and their parents were informed that anterior crossbite correction may be the first stage of orthodontic treatment.

**Cephalometric tracing**

The pretreatment and posttreatment cephalometric radiographs of each patient were digitized and analyzed using Viewbox (version 3.1.1.14; dHAL, Kifissia, Greece). Viewbox was used for cephalometric tracing and designing the analysis methods (Figure 3). In this study, overjet and overbite were presented using the chosen crossbite tooth. In each case, the most anterior tooth in the crossbite was chosen and was a central incisor or a lateral incisor.

For observing tooth movement in horizontal and vertical directions, two reference lines were constructed after referring to previous studies.6–8

**Measurement error and statistical analysis**

All cephalograms were traced and digitized by an investigator. The same investigator randomly selected 10 of 30 patients, obtained a total of 20 cephalometric films, and remeasured them after at least 2 weeks. Random errors were estimated using Dahlberg’s formula:

\[
Se = \sqrt{\frac{\sum d^2}{2n}}
\]

where \( Se \) is the method error (or standard deviation of the difference of each of the paired measurements from its pair mean), \( d \) is the difference between the first and second recordings, and \( n \) is the number of radiographs replicated. The combined measurement error was 0.78° for angular variables and 0.63 mm for linear variables; all individual errors were within the acceptable range.

Paired t tests were used for comparing the pretreatment and posttreatment cephalometric values. The Kruskal–Wallis test and Mann–Whitney U test were used for identifying intergroup differences. Multiple regression analysis was performed for identifying the factors affecting changes in crossbite correction. Twenty independent variables were entered into the regression analyses. All tests

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**Figure 2**  Anterior crossbite correction using a lingual arch with finger springs (LAFS): (a) before treatment; (b) appliance delivery; (c) crossbite correction; (d) follow-up or continuous orthodontic treatment.
Results

Thirty patients (13 female and 17 male; mean age, 12.11 ± 1.13 years) were included (Table 1). Most of the patients were aged between 7 and 15 years; only three patients were older than 20 years. The mean treatment time of anterior crossbite correction was 49.33 ± 3.74 days. After anterior crossbite was corrected, 10 patients with early mixed dentition were followed up every 3–6 months. Those patients with late mixed dentition and permanent dentition underwent full-mouth orthodontic treatment after crossbite correction.

Table 1 Sample description.

|               | Group 1          | Group 2          | Group 3          |
|---------------|------------------|------------------|------------------|
| No. of patients | 8                | 9                | 13               |
| Sex           | 4 males/4 females| 6 males/3 females| 7 males/6 females|
| Age (y)       | 14.16 ± 3.25     | 10.40 ± 1.15     | 12.03 ± 1.53     |
| Overjet       | −1.83 ± 0.53     | −3.28 ± 0.61     | −2.96 ± 0.37     |
| Molar relationship | I 4               | 7                | 2                |
|               | II 3              | 1                | 3                |
|               | III 1             | 1                | 8                |
| ANB (°)       | 2.96 ± 0.60       | 0.77 ± 1.11      | −0.67 ± 0.56     |
Table 2  Treatment changes in all patients.

| n = 30 | T0 Mean ± SE | T1 Mean ± SE | T1–T0 Mean ± SE |
|--------|--------------|--------------|-----------------|
| Age (y) | 12.11 ± 1.13 | 49.33 ± 3.74 |                  |
| Treatment duration |                |              |                  |

Skeletal

| Variable | Group 1 Mean ± SE | Group 2 Mean ± SE | Group 3 Mean ± SE | P-value |
|----------|-------------------|-------------------|-------------------|---------|
| SNA (°)  | 80.63 ± 0.67      | 79.25 ± 0.78     | 79.62 ± 0.70     | <0.05   |
| SNB (°)  | 79.89 ± 0.78      | 79.25 ± 0.78     | 79.46 ± 0.70     | <0.05   |
| ANB (°)  | 0.73 ± 0.51       | 1.45 ± 0.46      | 0.72 ± 0.16      | <0.05   |
| A to Nv (mm) | −0.39 ± 0.93    | −0.33 ± 0.99     | 0.06 ± 0.35     | <0.05   |
| Pog to Nv (mm) | −2.72 ± 1.69    | −4.59 ± 1.70     | −1.87 ± 0.53     | <0.05   |
| FMA (°)  | 25.83 ± 0.82      | 26.79 ± 0.86     | 24.88 ± 0.59     | <0.05   |
| Wits (mm) | −5.78 ± 0.99     | −2.87 ± 0.78     | 2.92 ± 0.67      | <0.05   |

Soft tissue

| Variable | Group 1 Mean ± SE | Group 2 Mean ± SE | Group 3 Mean ± SE | P-value |
|----------|-------------------|-------------------|-------------------|---------|
| U lip to E-line (mm) | 0.19 ± 0.75      | 1.20 ± 0.60      | 1.01 ± 0.52      | <0.05   |
| L lip to E-line (mm) | 4.93 ± 0.97      | 4.91 ± 0.88      | −0.01 ± 0.42     | <0.05   |

Table 3 shows that no significant differences were observed among the groups in age and treatment duration (P > 0.05).

The values of ANB, A to Nv, and Wits in Group 3 were significantly smaller than those in Group 1, and the value of U1 to NA was significantly larger in Group 3 than in Group 1 (P < 0.05). Changes in overbite were more significant in Group 3 than in Group 1 because the mean overbite was approximately 4 mm at the beginning of treatment and became approximately 0 mm after treatment. Moreover, changes in the upper lip position were more significant in Group 3 than in Group 1, with protraction of 2.46 mm. The upper incisors in Group 3 showed significantly more superior crown movements than those in Group 1 did (P < 0.05).

**Regression analysis**

Linear regression analyses (Table 5) were performed with the dependent factors of treatment duration and overjet, overbite, U1-NA, and U1 to NA changes; independent factors were the other variables listed in Table 2 and the number of crossbite teeth. When the dependent factor was the treatment duration or overbite, no significant change was observed (P > 0.05). A considerable increase in overjet was associated with an increase in U1 to NA and a decrease in L1 to NB.

**Rates of upper incisor movements**

Calculations of incisor movement rates in the horizontal and vertical directions are shown in Table 6. The mean rate of upper incisor crown forward movement was 3.2 mm/mo, and those of root intrusion and retraction were approximately 1 mm/mo. There was no significant difference among Groups 1, 2, and 3 (P > 0.05).

**Discussion**

According to our review of the literature on anterior crossbite correction, many studies were case reports with
In this study, the treatment objective was crossbite correction, which was associated with overjet changes. Furthermore, overjet changes were considerably associated with the distances of U1 to NA and L1 to NB (Table 5). In addition, mean lower incisor backward movement influenced overjet changes. Although the lower teeth were not fixed with the orthodontic appliance, their movement was significantly influenced by upper tooth movement.

Studies have reported different treatment durations depending on the treatment method used. According to a review article,\(^1\) the treatment durations of anterior crossbite correction with removable appliances, cemented appliances, fixed appliances, and functional appliances were 1–5 months, 3–4 weeks, from 6 weeks to 3 months, and from 9 weeks to 15 months, respectively. In our study, 30 patients with one to four incisors in crossbite were treated in an average of 7 weeks. According to Tables 5 and 6, the treatment duration and the crossbite correction rate were not significantly different among the groups. This finding indicated that our treatment method was efficient and independent of the number of crossbite teeth.

Many treatment methods are available for correcting anterior crossbites, and each appliance has advantages and disadvantages. In this study, the LAFS required no patient compliance and efficiently achieved anterior crossbite correction regardless of the number of crossbite teeth. In addition, the LAFS was placed on the lingual side, and the appearance was more aesthetically pleasing than that of other fixed appliances. A disadvantage of using this appliance is palatal impingement occurring when the appliance slips from its original position. This problem could be resolved by maintaining the finger spring on the palatal surface of the incisor with a composite resin. LAFS may cause food impaction, but oral hygiene instruction could considerably reduce the possibility of periodontal inflammation. Some authors have asserted that an appliance with a bite plane for disocclusion is required to correct anterior crossbite. However, Graf\(^1\) reported that the total time of tooth contact in 24 hours was 17.5 minutes. In our study, anterior crossbites were corrected easily with no bite plate or molar restoration for performing disocclusion. Even in a deep overbite case, upper incisor protraction could be easily achieved in anterior crossbite correction.

This study introduced an efficient and stable method to correct anterior crossbite, and that was an important
dentition, and four patients lost contact. The limitations of orthodontic treatment when they were in permanent dentition results were stable. Six patients had full-mouth or- thodontic treatment. In our study, all of them had positive overjet and overbite after at least 2 years of follow-up; these treatment results were stable. Six patients had full-mouth orthodontic treatment when they were in permanent dentition, and four patients lost contact. The limitations of this study were the use of two-dimensional (2D) cephalometric films and crossbite tooth selection. A cephalometric radiograph is considered a 2D projection of 3D tooth movement. Computed tomography scans of children cannot be easily acquired because of parents’ concerns regarding radiation exposure. Two or more anterior crossbite teeth did not have the same response to the force of the LAFS; however, we examined treatment changes in only one tooth. For cases with more than one tooth in crossbite, the images of incisors could not be easily identified. Therefore, we chose the most anterior teeth in crossbite for representing the movement of crossbite teeth. The interval of return was 3 weeks or 4 weeks, and crossbite correction may be achieved at the 1st week or 2nd week. It would have error in calculation of treatment time, and the significant difference among groups may exist. It is the limitation of this study because patients would not return for checkup every day.

In conclusion, LAFS had an aesthetic advantage and required no patient compliance. Anterior crossbite correction did not need increasing bite appliances. Skeletal changes in clockwise mandibular rotation were attributed to dental changes. Age and treatment duration did not

| Table 4 | Treatment effects among groups with different numbers of crossbite teeth. |
|---------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
|         | Group 1 | Group 2 | Group 3 | All |
| Number of patients | 8 | 9 | 13 | 30 |
| Age (y) | 14.16 ± 3.25 | 10.40 ± 1.15 | 12.03 ± 1.53 | NS |
| Treatment duration | 45.50 ± 8.05 | 46.67 ± 3.52 | 53.54 ± 6.83 | NS |
| Pretreatment ANB (°) | 2.96 ± 0.60 | 0.77 ± 1.11 | −0.67 ± 0.56 | 1,3 |
| A to Nv (mm) | 4.64 ± 2.10 | −2.63 ± 1.09 | −1.92 ± 0.93 | 1,2, 1,3 |
| Wits (mm) | −1.39 ± 1.01 | −7.43 ± 2.50 | −7.35 ± 0.94 | 1,2, 1,3 |
| U1 to NA (mm) | −1.04 ± 1.23 | 2.40 ± 1.69 | 4.92 ± 0.86 | 1,3, 2, 3 |
| Change Overbite (mm) | 3.16 ± 0.70 | 1.41 ± 0.98 | 0.42 ± 0.57 | 1,2, 1,3 |
| U lip to E-line (mm) | −0.16 ± 0.49 | −1.63 ± 1.11 | −4.09 ± 0.99 | 1,3 |
| Tooth movement U1 crown-H | −1.30 ± 0.92 | −0.28 ± 0.98 | 1.25 ± 0.76 | 1,3 |

*Significant at P < 0.05 level.

| ANB = Angle of A-N-B points; NA = connecting line of A and N; NS = not significant. |

| Table 5 | Multiple regression analysis of measurement variable effects on overjet, U1-NA, and U1 to NA. |
|---------|----------------------------------|----------------------------------|----------------------------------|
| Overjet |                                  |                                  |                                  |
|         | B      | SE     | t      | P      |
| U1 to NA (mm) | 1.02 | 0.06 | 16.12 | <0.001 |
| L1 to NB (mm) | −0.99 | 0.11 | −9.44 | <0.001 |
| U1-NA |                                  |                                  |                                  |
| U1-SN | 0.99 | 0.01 | 148.16 | <0.001 |
| U1 to NA (mm) | 0.94 | 0.06 | 16.169 | <0.001 |

H = tooth movement in the horizontal direction; SE = standard error; V = tooth movement in the vertical direction.

| Table 6 | Rates of upper incisor movement in horizontal and vertical directions. |
|---------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
|         | Group 1 (n = 8) | Group 2 (n = 9) | Group 3 (n = 13) | All (n = 30) | P  |
| Rate (mm/mo) |                                  |                                  |                                  |                                  |    |
| U1 crown-H | 3.10 ± 0.61 | 3.37 ± 0.74 | 3.14 ± 0.52 | 3.20 ± 0.34 | NS |
| U1 crown-V | −1.13 ± 0.58 | −0.34 ± 0.78 | 0.35 ± 0.43 | −0.14 ± 1.90 | NS |
| U1 root-H | −0.63 ± 1.23 | −1.13 ± 0.85 | −0.86 ± 0.63 | −0.88 ± 0.48 | NS |
| U1 root-V | −1.64 ± 0.79 | −1.81 ± 0.67 | −0.44 ± 0.38 | −1.17 ± 0.34 | NS |

H = tooth movement in the horizontal direction; NS = no significant group differences at P = 0.05; V = tooth movement in the vertical direction.
significantly vary among the three groups, and the mean treatment efficiency was satisfactory regardless of the number of crossbite teeth. Linear regression analyses showed an increase in overjet, which was associated with an increase in U1 to NA and a decrease in L1 to NB. In our study, anterior crossbite correction at a short period by using LAFS is efficient, and these cases were dental crossbite, not of skeletal origin.

Conflicts of interest

The authors have no conflicts of interest relevant to this article.

References

1. Jirgensone I, Liepa A, Abeltins A. Anterior crossbite correction in primary and mixed dentition with removable inclined plane (Bruckl appliance). Stomatologija 2008;10:140–4.
2. Croll TP. Correction of anterior tooth crossbite with bonded resin-composite slopes. Quintessence Int 1996;27:7–10.
3. Yaseen SM, Acharya R. Hexa helix: modified quad helix appliance to correct anterior and posterior crossbites in mixed dentition. Case Rep Dent 2012;2012:860385.
4. Mershon JV. The removable lingual arch as an appliance for the treatment of malocclusion of the teeth. Int J Orthodontia 1918;4:578–87.
5. Ross JW. Present day lingual arch therapy. Am J Orthod Dentofacial Orthop 1944;30:1–20.
6. Hayashida H, Ioi H, Nakata S, et al. Effects of retraction of anterior teeth and initial soft tissue variables on lip changes in Japanese adults. Eur J Orthod 2011;33:419–26.
7. Kocadereli I. Early treatment of posterior and anterior crossbite in a child with bilaterally constricted maxilla: report of case. ASDC J Dent Child 1998;65:41–6.
8. Chew MT. Soft and hard tissue changes after bimaxillary surgery in Chinese Class III patients. Angle Orthod 2005;75:959–63.
9. Dahlberg G. Statistical methods for medical and biological students. London: George Allen and Unwin, 1940.
10. Borrie F, Bearn D. Early correction of anterior crossbites: a systematic review. J Orthod 2011;38:175–84.
11. Graf H. Bruxism. Dent Clin North Am 1969;13:659–65.