Efficacy of Nickel-Titanium Palatal Expanders


ABSTRACT

Objective: Timely treatment of narrow maxilla by means of maxillary expansion during the primary or transitional dentition is recommended to reestablish optimal function in order to normalize dental, skeletal and neuromuscular growth. The aim of this study was to assess the amount of orthodontic and orthopedic expansion achieved in the maxilla and to evaluate cephalometrically the various postural changes in the maxilla and mandible with the use of nickel-titanium palatal expander.

Materials and methods: A total of ten subjects, five males and five females were selected from a survey conducted on 2000 children in age range of 7 to 15 years, belonging to various schools. Their study cast, cephalograms and occlusal radiographs were used for the study. Maxillary intermolar width, maxillary intercanine width and mandibular intermolar width were measured on study cast using Vernier caliper. Certain measurements were done on the cephalogram and occlusal radiograph.

The data obtained out of various measurements made on study casts, frontal, lateral cephalograms and occlusal radiographs at the pretreatment, postexpansion and postretention stages were statistically analyzed. All the observations were made by two observers. The interexaminer variability was calculated using t-test. The mean and standard deviations were calculated and student’s t-test (paired) was applied to determine the amount of change, variability of change and significance of change, respectively.

Results: A constant force exerted by nickel-titanium palatal expander had orthopedic effects in growing age group indicated by statistically increase in the maxillary width. The ratio of relative orthodontic to orthopedic effect with this appliance was 6:1. Consequent to maxillary expansion, there occurred a significant downward movement of the maxillae and downward and backward rotation of the mandible. There was opening of midpalatal suture during active phase followed by suture remineralization during the retention period.

Conclusion: To conclude, a Ni-Ti expander brings about expansion by a combination of orthodontic and orthopedic effects by an increase in maxillary intermolar, maxillary intercanine and mandibular intercanine widths as also the opening of the midpalatal suture.

Keywords: Nickel-titanium expander, Maxillary expansions, Maxillary width.


INTRODUCTION

The narrow maxilla is one of the common problems encountered in orthodontics which may manifest as posterior crossbite. Timely treatment of such transverse discrepancies, by means of maxillary expansion during the primary or transitional dentition is recommended to reestablish optimal function in order to normalize dental, skeletal and neuromuscular growth. The primary aim of maxillary expansion is to coordinate the maxillary and mandibular dental bases by increasing the arch width and thus eliminate interarch width discrepancies. This can be accomplished by means of rapid or slow maxillary expanders.

Rapid maxillary expansion produces mainly an orthopedic response as heavy forces, in the range of 3 to 10 pounds are generated daily. Such heavy forces can cause disruptive changes within the sutures and bring about root resorption of the teeth. Slow maxillary expansion produces more physiologic response of the midpalatal suture as the suture is opened at the same rate at which it is repaired. It produces less tissue resistance in the suture and allows better bone formation. Both these factors help to minimize the postexpansion relapse.

Dr Wnadell V Arndt of USA, in 1993, developed a pre-programmed, tendon looped, semifixed, nickel-titanium palatal expander, which produces light continuous forces producing slow maxillary expansion (Figs 1 and 2). It is available in eight sizes and exerts forces in the range of 180 to 300 gm. NiTi alloy is stronger, flexible and exerts longer range of action than stainless steel. It has a transition temperature of 94°F, when chilled, it becomes more flexible, when up, the metal stiffens and shape memory is restored and the appliance begins to exert a light continuous force on the teeth and palatal suture. Arndt used this expander on several cases of unilateral as well as bilateral posterior crossbites and demonstrated his results by means of study casts only. No attempts were made to determine the relative amount of orthopedic vs orthodontic expansion produced by the appliance. Moreover, various expected/probable spatial, functional changes, posture of maxilla,
mandible, degree of bite opening, change in the size of nasal cavity and effect on the mandibular arch width remained undocumented. The aim of this study was to fill-up the vacuum of knowledge by assessing the amount of orthodontic and orthopedic expansion achieved in the maxilla and to evaluate cephalometrically the various postural changes in the maxilla and mandible with the use of nickel-titanium palatal expander.

MATERIALS AND METHODS

The present study was conducted at the Department of Orthodontics and Dentofacial Orthopedics, AB Shetty Memorial Institute of Dental Sciences, Derlakatte, Mangalore after obtaining ethical clearance. Four subjects, five males and five females, were selected from a survey conducted on 2000 children, in age range of 7 to 15 years, belonging to various schools of Mangalore city. Prior informed consent was obtained from the parents of the subjects. Subjects having unilateral or bilateral posterior crossbite were selected for the study. Case selection was made after evaluation of study casts, frontal and lateral cephalograms, standard occlusal radiographs of the maxilla and intraoral and extraoral photographs. Subjects having gross periodontal disease, extensive caries, congenitally missing teeth, anterior open bite and with previous history of orthodontic treatment were excluded. Maxillary intermolar width, maxillary intercanine width and mandibular intermolar width, were measured on study cast using Vernier caliper.

The following measurements were made on the study cast as described by Frank and Engel, using Vernier caliper, having an accuracy of 0.5 mm (Figs 3A to C):

Maxillary intermolar width: The distance between the tip of the distobuccal cusp of maxillary first molars across the arch (Fig. 3A).

Maxillary intercanine width: The distance between the cusp tips of the maxillary canine of each side (Fig. 3B).

Mandibular intermolar width: The distance between the tip of the distobuccal cusp of the mandibular first molars across the arch (Fig. 3C).

These measurements were made by two observers. The reliability for accuracy of the measurements was checked by applying student’s t-test for paired observations. The interobserver difference was found to be nonsignificant statistically. Therefore, the observations recorded by the main observer were taken.
CEPHALOGRAMS

Posteroanterior and lateral cephalograms were recorded with teeth in centric occlusion and with similar exposure parameters. All the cephalometric measurements were recorded up to 0.5 mm/0.5 degree.

THE FOLLOWING CEPHALOMETRIC LANDMARKS WERE RECORDED ON EACH OF THE CEPHALOGRAMS AND USED FOR THE STUDY

Landmarks as defined by Rickets

1. $A_6$ (upper molar): A point on the occlusal plane located perpendicular to the buccal surface of crown of the upper permanent first molar.
2. $B_6$ (lower molar): A point on the occlusal plane located perpendicular to the buccal surface of the crown of lower permanent first molar.
3. Jugal process: The most lateral and inferior point on the zygomaticomaxillary suture.
4. $Po$ (anatomic porion): The most superior point at the external auditory meatus.
5. $CF$ (center of face): The point of intersection of pterygoid root vertical to the Frankfort horizontal plane.
6. $Pt$ (pterygoid): The junction of pterygomaxillary fissure and the foramen rotundum.
7. $DC$: A point in the center of condylar neck along Ba-N plane.
8. $Xi$: Geometric center of ramus.
9. $PM$ (protrubence mentii): The point at which the shape of symphysis changes from convex to concave.
10. $Gn$ (cephalometric gnathion): A point at the intersection of facial and mandibular plane.
11. $Go$ (cephalometric gonion): A point at intersection of the ramus and mandibular plane.

Landmarks as defined by Rakosi (Fig. 4A)

1. $Point A$ (subspinale): The deepest midline point in the curved bony outline from the base to the alveolar process of maxilla.
2. $Or$ (orbitale): The lowermost point of the bony orbit in the radiographs.
3. $Ba$ (basion): The lowermost point on the anterior margin of foramen magnum in the median plane.
4. $ANS$ (anterior nasal spine): The tip of bony anterior nasal spine in the median plane.
5. $PNS$ (posterior nasal spine): A point where palatal plane meets with the pterygomaxillary fissure.
6. $N$ (nasion): The most anterior point of nasofrontal suture in median plane.
7. $POG$ (pogonion): The most anterior point on the bony chin.

CEPHALOMETRIC PLANES USED IN THE STUDY

The following cephalometric planes as defined by Rickets on frontal cephalogram (Fig. 4B):

1. Frontal occlusal plane: A plane joining the occlusion of upper and lower molars on each side.
2. Frontal facial plane: Passing from the center of the bony nasal cavity at right angles to the occlusal plane.
The following cephalometric planes as defined by Rickets:

1. **Frankfort horizontal plane**: Extending from porion to orbitale (using anatomic porion).
2. **Facial plane**: Extending from nasion to pogonion.
3. **Mandibular plane**: Extending from gonion to gnathion (using cephalometric gonion and gnathion).
4. **Pterygoid vertical plane**: A vertical line drawn through the distal radiographic outline of the pterygomaxillary fissure and perpendicular to the Frankfort horizontal plane.
5. **Basion-nasion plane**: Extending from basion to nasion.
6. **Facial axis**: Extending from the point Pt to cephalometric gnathion (Pt to Gn).
7. **Condylar axis**: Extending from DC to Xi point.
8. **Corpus axis**: Extending from Xi to PM.

**Cephalometric Plane as defined by Rakosi**

**Palatal plane**: A plane joining ANS and PNS.

**MEASUREMENTS MADE ON FRONTAL (P-A) CEPHALOGRAM (FIG. 6A)**

**Linear Measurements (in mm)**

1. **Maxillary width**: The distance between right and left jugal process.
2. **Maxillary intermolar width**: The distance between points A6 and 6A.
3. **Maxillary intercanine width**: The distance between cusp and tips of maxillary canines.
4. **Mandibular intermolar width**: The distance between the points B6 and 6B.
5. **Nasal width**: The greatest distance between the right and left lateral bony walls of nasal cavity.
6. **Average molar relation**: The average of horizontal distance between the buccal surface of maxillary and mandibular first molars on the respective sides measured along the occlusal plane.
Average maxillomandibular relation: The average of the left and right distances from the maxilla (jugal process) to the frontal facial plane on the respective side.

MEASUREMENTS MADE ON LATERAL CEPHALOGRAMS (FIG. 6B)

Linear Measurements (in mm)
1. Convexity at point A: The distance between N Pog to Point A.

Angular Measurements (in degree)
1. Palatal plane angle: The angle between Frankfort horizontal plane and palatal plane.
2. Maxillary angle: The angle between nasion-basion plane and nasion point A plane.
3. Mandibular plane angle: The angle between Frankfort plane and mandibular plane.
4. Facial axis: The angle between basion-nasion and the plane from rotundum (PT) to gnathion.
5. Facial depth: The angle between facial plane and Frankfort horizontal plane.
6. Lower face height: The angle between ANS Xi to Xi-PM
7. Mandibular arc angle: The angle between condylar axis and corpus axis.

OCCLUSAL RADIOGRAPHS
Standard occlusal radiographs of maxilla for each individual were taken pretreatment, postexpansion and postretention.

RESULTS
The total appliance wear time including a 12 weeks retention period was 26.13 ± 1.26 weeks. The mean number of adjustments required was 0.8 ± 0.42. In two of the cases on one, the appliance became loose and therefore molar bands had to be recemented in position. The desired amount of expansion was achieved in 9.42 to 19.28 weeks with a mean of 14.13 ± 1.26 weeks. Palatal expansion was considered to be adequate and successful when the occlusal slopes of maxillary lingual cusps contacted the occlusal slopes of mandibular buccal cusps (Fig. 7).

Phase I (Changes from Pretreatment to Postexpansion Stage)
Changes exhibited in various parameters on the study cast, linear and angular measurements on the cephalograms are presented in Tables 1 to 3 respectively. There was a significant decrease in the average maxillomandibular relation indicating correction of posterior crossbite. No significant difference existed between the increase in maxillary intermolar width when the study casts (9.47±1.73 mm) and the frontal cephalograms (10.2 ± 1.87 mm) were compared.

Table 1: Linear dental changes observed on study casts during phase I (active expansion period)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameters</th>
<th>Range (in mm)</th>
<th>Mean increase (mm)</th>
<th>SE</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Maxillary intermolar width</td>
<td>7.5-12</td>
<td>9.47 ± 1.73</td>
<td>0.548</td>
<td>17.28</td>
<td>0.001****</td>
</tr>
<tr>
<td>2.</td>
<td>Maxillary intercanine width</td>
<td>2-5.7</td>
<td>3.33 ± 1.11</td>
<td>0.350</td>
<td>9.51</td>
<td>0.001****</td>
</tr>
<tr>
<td>3.</td>
<td>Mandibular intermolar width</td>
<td>0.5-2</td>
<td>0.45 ± 0.599</td>
<td>0.189</td>
<td>0.38</td>
<td>0.05**</td>
</tr>
</tbody>
</table>

**** Highly significant at p < 0.001; ** Significant at p < 0.05

Table 2: Linear dental and skeletal changes observed on frontal cephalogram during phase I (active expansion period)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameters</th>
<th>Range (in mm)</th>
<th>Mean increase (mm)</th>
<th>SE</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Maxillary width</td>
<td>1-3</td>
<td>1.6 ± 0.715</td>
<td>0.226</td>
<td>0.08</td>
<td>0.001****</td>
</tr>
<tr>
<td>2.</td>
<td>Maxillary intermolar width</td>
<td>6-12</td>
<td>10.2 ± 1.87</td>
<td>0.592</td>
<td>7.22</td>
<td>0.001****</td>
</tr>
<tr>
<td>3.</td>
<td>Maxillary intercanine width</td>
<td>2-4.5</td>
<td>3.45 ± 0.88</td>
<td>0.279</td>
<td>2.36</td>
<td>0.001****</td>
</tr>
<tr>
<td>4.</td>
<td>Mandibular intermolar width</td>
<td>0.5-2</td>
<td>0.45 ± 0.599</td>
<td>0.189</td>
<td>0.38</td>
<td>0.05**</td>
</tr>
<tr>
<td>5.</td>
<td>Nasal width</td>
<td>0.5-1</td>
<td>0.25 ± 0.125</td>
<td>0.112</td>
<td>0.23</td>
<td>0.1*</td>
</tr>
<tr>
<td>6.</td>
<td>Average molar relation I</td>
<td>4-7</td>
<td>5.45 ± 0.942</td>
<td>0.298</td>
<td>8.28</td>
<td>0.001****</td>
</tr>
<tr>
<td>7.</td>
<td>Average maxillomandibular relation</td>
<td>1-2</td>
<td>−1.15 ± 0.527</td>
<td>0.168</td>
<td>0.03</td>
<td>0.001****</td>
</tr>
</tbody>
</table>

****Highly significant at p < 0.001; **Significant at p < 0.05; *Significant at p < 0.1
The relative orthodontic and orthopedic response produced with nickel-titanium palatal expander, was a ratio of 6:1 indicating 16% of response obtained was skeletal. Occlusal radiographs of maxilla showed radiographic evidence of suture opening. The pattern of separation was greatest anteriorly with a progressive decrease apparent posteriorly.

**Phase II (Changes from Postexpansion to Postretention)**

Changes exhibited in various parameters on the study cast, linear and angular measurements on the frontal and lateral cephalograms are presented in Tables 4 to 6 respectively.

There was a significant increase in mandibular intermolar width, thus showing that the increase in mandibular width tended to follow suit the maxillary expansion.

Frontal cephalogram showed significant increase in mandibular intermolar width whereas nonsignificant in all other parameters. Lateral cephalogram (Table 6) showed significant increase in mandibular plane angle, facial axis, lower face height and mandibular arc angle and nonsignificant in other parameters showing that the mandible tended to come back to its original position.

Occlusal radiographs of maxilla showed recalcification of midpalatal suture evidenced radiographically as radiopaque.

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**Table 3: Linear and angular changes observed on lateral cephalogram during phase I (active expansion period)**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameters</th>
<th>Range (in mm)</th>
<th>Mean increase (mm)</th>
<th>SE</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Convexity at A</td>
<td>0-1</td>
<td>–0.1 ± 0.273</td>
<td>0.581</td>
<td>0.25</td>
<td>0.02</td>
</tr>
<tr>
<td>2.</td>
<td>Palatal plane</td>
<td>0-0.5</td>
<td>–0.1 ± 0.21</td>
<td>0.066</td>
<td>1.96</td>
<td>NS</td>
</tr>
<tr>
<td>3.</td>
<td>Maxillary height</td>
<td>0.1-0.2</td>
<td>+0.45 ± 0.599</td>
<td>0.189</td>
<td>2.38</td>
<td>0.02</td>
</tr>
<tr>
<td>4.</td>
<td>Mandibular plane angle</td>
<td>0-1</td>
<td>–0.1 ± 0.21</td>
<td>0.066</td>
<td>1.96</td>
<td>NS</td>
</tr>
</tbody>
</table>

***Highly significant at p < 0.05; **Significant at p < 0.05; NS: Not significant

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**Table 4: Linear dental changes observed on study casts during phase II (Retention period)**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameters</th>
<th>Range (in mm)</th>
<th>Mean increase (mm)</th>
<th>SE</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Maxillary intermolar width</td>
<td>0.1-0.2</td>
<td>–0.2 ± 0.349</td>
<td>0.111</td>
<td>1.4</td>
<td>NS</td>
</tr>
<tr>
<td>2.</td>
<td>Maxillary intercanine width</td>
<td>0.1-0.2</td>
<td>+0.45 ± 0.599</td>
<td>0.189</td>
<td>2.38</td>
<td>0.02</td>
</tr>
</tbody>
</table>

***Significant at p < 0.05; NS: Not significant

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**Table 5: Linear and skeletal changes observed on frontal cephalogram during phase II (retention period)**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameters</th>
<th>Range (in mm)</th>
<th>Mean increase (mm)</th>
<th>SE</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Maxillary width</td>
<td>0-1</td>
<td>–0.1</td>
<td>0.1</td>
<td>1</td>
<td>NS</td>
</tr>
<tr>
<td>2.</td>
<td>Maxillary intermolar width</td>
<td>0.1-0.2</td>
<td>+0.4 ± 0.734</td>
<td>0.189</td>
<td>2.38</td>
<td>0.02</td>
</tr>
</tbody>
</table>

***Significant at p < 0.05; NS: Not significant

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**Table 6: Linear and angular changes observed on lateral cephalogram during phase II (retention period)**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Range (in mm)</th>
<th>Mean increase (mm)</th>
<th>SE</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convexity at A</td>
<td>0-1</td>
<td>–0.1 ± 0.316</td>
<td>0.1</td>
<td>1</td>
<td>NS</td>
</tr>
<tr>
<td>Palatal plane</td>
<td>0-0.5</td>
<td>–0.1 ± 0.21</td>
<td>0.066</td>
<td>1.96</td>
<td>NS</td>
</tr>
<tr>
<td>Maxillary height</td>
<td>0-1</td>
<td>+0.45 ± 0.599</td>
<td>0.189</td>
<td>2.38</td>
<td>0.02</td>
</tr>
<tr>
<td>Mandibular plane angle</td>
<td>0.1-0.2</td>
<td>–0.1 ± 0.21</td>
<td>0.066</td>
<td>1.96</td>
<td>NS</td>
</tr>
</tbody>
</table>

***Highly significant at p < 0.02; **Significant at p < 0.05; *Significant at p < 0.05; NS: Not significant
obliteration of suture on the termination of 12 weeks (3 months) retention indicating that there was no evidence left to show that the midpalatal suture opened up in phase I.

DISCUSSION

Maxillary expansion, by means of slow maxillary expansion undoubtedly, has created a great impact on the contemporary orthodontic thinking and therapy. In the present study, an attempt has been made to analyze the effects of a newly developed palatal expander, namely the nickel-titanium palatal expander, producing slow maxillary expansion.

The mean increase in maxillary intermolar width, in present study, was comparable to that reported by Wertz and twice as much as reported by Hicks, Bell, Frank and Arndt. This difference might be because of the amount of expansion needed in different studies. In phase II, there was an insignificant decrease in maxillary intermolar width and maxillary intercanine width (indicating that the nickel-titanium palatal expander used in the present study was rigid enough to hold the expanded segments in place and worked as a fixed retainer) which are contrary to the findings of Skeiller, Hicks and Kreb.

The mean increase in the mandibular intermolar width, is in conformity to that observed by Hicks but more as compared to Bell and LeCompte. This difference could be attributed to a shorter period used by Bell and LeCompte. Even in phase II, mandibular intermolar width increase was significant and similar to that reported by Wertz.

The orthopedic changes, in respect of increase in maxillary width and decrease in average maxillomandibular width in our study, were comparatively higher than found by Frank and Engel. The difference in appliance design could be the attributable reason.

Increase in nasal width was observed during the active expansion period which is in conformity with the findings reported by Wertz, Frank and Haas. There was insignificant relapse in phase II. There was no significant change in convexity at point A, ANS and PNS position during the phase of expansion while there was a significant increase in maxillary height indicating downward movement of maxilla which is similar to Wertz and Frank.

In the present study, there was a significant increase in mandibular plane angle (p < 0.02) and facial axis angle (p < 0.02) indicating bite-opening associated with expansion which is similar to Wertz, Hicks and Frank. Thus, indicating significant downward movement of maxilla with no forward movement.

The change in facial depth and mandibular arc angle was in accordance with that of Wertz who reported that the mandible in most of the cases rotated backward although the forward rotation of the mandible was also seen in few cases.

There was a significant change in all the four parameters viz, mandibular plane angle, facial axis angle, lower face height and mandibular arc angle which indicated that the mandible tended to return to its original posture during the retention phase. These findings compare favorably with those by Wertz and Haas, in their studies on rapid maxillary expansion.

Increase in transverse dimension of maxillary arch indicated palatal suture opening. This is in accordance to findings observed by Ferrario et al.

Relative orthodontic and orthopedic changes observed were similar to that found by Frank and Engel.

Standard occlusal radiographs of maxillae showed the pattern of palatal suture opening was greater anteriorly than posteriorly, which is similar to that reported by Harberson and Myers, Bell and LeCompte, Wertz and Haas. The reason for this differential response could be the greater resistance to skeletal opening offered by zygomatic buttress in the posterior region. However, study casts and frontal cephalograms demonstrated greater change posteriorly than anteriorly where more of the orthodontic than orthopedic effect was observed. These findings are also in conformity to that observed by Hicks, Bell and LeCompte and by Wertz. There was an evidence of obliteration of midpalatal suture at the end of retention period, which was in accordance with the findings by Ekstrom, Harberson and Myers and Bell and LeCompte, indicating remineralization.

CONCLUSION

The nickel-titanium palatal expander brings about an increase in maxillary as well as mandibular dental arch width as indicated by increase in maxillary intermolar, maxillary intercanine, mandibular intermolar width and the average molar relation. A constant force exerted by the expander in the range of 250 to 300 gm had definite effects in growing age group as indicated by a statistically significant increase in the maxillary width as seen on frontal cephalogram. The ratio of relative orthodontic to orthopedic effect with this appliance was approximately 6:1. Consequent to maxillary expansion, there occurred a significant downward movement of the maxillae and downward and backward rotation of the mandible, except in the case where forward rotation was observed. The posture attained by maxillae was stable during the retention period while the mandible tended to come forward to its original position. Radiographic evidence of midpalatal suture opening during active phase was seen on all the 10 cases, which was followed by suture remineralization during the retention period. The passive expander proved to be sufficiently rigid and 12 weeks of fixed retention period was adequate for the retention of expanded maxillary segments which was evidence by no relapse.

REFERENCES