Rapid maxillary expansion: effects on palatal area investigated by computed tomography in growing subjects

ABSTRACT

Aim The aim of this prospective study was to evaluate the effects of rapid maxillary expansion (RME) on the palatal area as assessed by low-dose CT before treatment (T0), at the end of active expansion (T1) and after a retention period of 6 months (T2).

Materials and Methods The study sample comprised 17 prepubertal subjects (mean age 11.2 years) with constricted maxillary arches. Total amount of expansion was 7 mm in all subjects. Multi-slice low-dose CT scans were taken at T0, T1, and T2. On axial CT scanned images a circle line corresponding to the palatal area was drawn and the area inside the circle registered at all three observation times. The area was measured in mm². Statistical comparisons were carried out with Friedman test with post-hoc tests (P<0.05).

Results The palatal area showed a significant increase from T0 to T1 and from T0 to T2 as a consequence of the opening of the midpalatal suture after RME.

Conclusion Opening the midpalatal suture by using orthopedic forces allowed to extend the area of the maxilla. After a 6-months retention period the palatal area demonstrated a stable increase due to a bone deposition along the midpalatal suture in both the anterior and posterior parts of the maxilla.

Keywords Computed tomography; Imaging 3D; Palatal vault; Rapid maxillary expansion.

Introduction

The correlations and connections between the stomatognathic system and other apparatuses are often the object of investigations. In particular, the correction of skeletal transverse problems of the maxilla can be associated with favourable therapeutic effects on hearing, swallowing and nasal breathing [Braun, 1966; Gray, 1975]. Several authors have evaluated the effects of Rapid Maxillary Expansion (RME) and they reported a decrease in nasal resistance, an increase in respiratory area and an improvement in conductive hearing loss after treatment because the palatal area is the area where the tongue should be located and the palatal processes of the maxilla correspond to the floor of the nasal cavities [Ceylan et al., 1996; Basciftci et al., 2002; Buccheri et al., 2004]. Indeed patients with constricted maxillary arches tend to posture the tongue in a low position and the expansion of the palatal region allows to reduce low or forward tongue posture [Brodie, 1950]. RME causes improvements in nasal respiration and in oral posture by increasing the palatal area and by lowering of the palatal vault [Haas, 1961; Starnbach et al., 1961; Wertz, 1970]. RME was established as a valid treatment method to correct transverse maxillary deficiencies, since the effects of this procedure were substantiated by radiography [Derichsweiler, 1953; Krebs, 1964]. In the literature a wide standard radiographic documentation is reported and 3D more sophisticated techniques for evaluation of morphological changes in the dentofacial complex have been proposed in the last ten years [Sandikcioglu and Hazar, 1997; da Silva Filho et al., 1995; da Silva Filho et al., 2006; Podesser et al., 2007]. In particular the effects of RME on the palatal vault have been analysed by linear measurements on dental casts, on posteroanterior cephalograms, and on computed tomography (CT) scanned images [Rungcharassaeng et al., 2007; Lione et al., 2008; Ballanti et al., 2009; Garib et al., 2005; Habersack et al., 2007; Garret et al., 2008; Phatouros et al., 2008]. Currently, the number of scientific investigations conducted on CT scans is limited, while it would add valuable information to existing observations on axial CT scans of the palatal area.

The aim of this prospective study was to analyse the changes of the palatal area after RME as assessed by low-dose CT before treatment (T0), at the end of active expansion (T1) and after a retention period of 6 months (T2). The palatal area was studied by using a diagnostic tool reported in literature to evaluate glenoid bone loss [Nofsinger et al., 2010].

This radiographic method of investigation is able to show the modification of the palatal area after treatment by using a standardised circle area that is not influenced by tooth position, alveolar and skeletal morphology.
Materials and methods

The prospective study sample comprised 17 Caucasian subjects (7 males and 10 females) with a mean age of 11.2 years (range 8-14 years) who sought orthodontic treatment at the Department of Orthodontics of the University of Rome “Tor Vergata”. Selection criteria were: constricted maxillary arches, and stages in cervical vertebral maturation as assessed on lateral cephalograms ranging from CS1 to CS3 (prepubertal) [Baccetti et al., 2005]. This project was approved by the Ethical Committee of the University of Rome “Tor Vergata”, and informed consent was obtained from the parents of the patients.

Each patient underwent a standardised protocol with RME in the form of the Butterfly Palatal Expander that followed the basic design of Haas [Cozza et al., 2001]. The expansion screw was activated at 2 turns per day (0.25 mm per turn) for 14 days, thus reaching the total amount of screw expansion of 7 mm in all subjects. Then, the screw was tied off with a ligature wire, and the expander was kept in place as a passive retainer for 6 months.

Multi-slice low-dose CT scans were taken before rapid palatal expansion (T0), at the end of the active expansion phase (T1), and after a retention period of 6 months (T2). The scans were carried out by a single trained radiographer at the same scanner console with the primary indication of evaluating the exact position of displaced intraosseous canines in the maxilla. All exams were performed at the Department of Radiology, University of Rome, “Tor Vergata”, with a CT scanner endowed with a Dentascan reconstruction program used to study the maxillofacial region (Light-Speed 16, General Electric Medical System, Milwaukee, Winsconsin, USA). This machine is equipped with 16 detector rows and has a minimal rotation time of 0.5 s, given a collimation between 0.75 and 1.5 mm with dose calibration. Subsequent scans were taken with a 1.25 mm slice thickness, 0.6 mm interval, 11.25 mm table speed/rotation, 100 mA, 13.7 cm FOV, 512x512 matrix, 0° gantry angle, and following a low dose protocol with 80 KV instead of the standard CT setting of 120 KV.

Each patient was positioned horizontally on the scanner table with the Camper’s plane perpendicular to the ground. The perpendicular light beams of the machine were used to standardise the head position in the three planes, thus allowing a comparison of the images achieved before, during, and after expansion. During the CT scanning, patients were biting on a piece of gauze to keep the maxillary and the mandibular teeth separated, and to avoid the overlapping of dentofacial structures.

Standardised axial CT images parallel to the palatal plane and passing through trifurcation of the right upper first molar were acquired and enlarged by 3x magnification factor with a specific software (Light-Speed 16, General Electric Medical System, Milwaukee, Winsconsin, USA). On the enlarged images a circle line was drawn passing through the following points:
1. The external aspect of the palatal cortical plate of the right maxillary first molar.
2. The external aspect of the palatal cortical plate corresponding to the right maxillary central incisor.
3. The external aspect of the palatal cortical plate of the left maxillary first molar.

The area inside the circle was registered and measured at all three observation times in square millimeters (mm²). The circle areas were placed by a single trained operator for the calculation of extension at T0, T1, and T2 (Fig. 1, 2). The operator was blinded to the case being measured.

Statistical analysis
A single operator (RL) performed all measurements.
at the same scanner console, and repeated all measurements after one month. Systematic and random errors on the measures repeated on the 17 subjects at all observations periods were calculated with paired t-tests and Dahlberg’s formula [Dahlberg, 1940], respectively. No statistically significant differences (P > 0.05) were found between the first and the second measurements for any of the analysed variables; the range for random errors was 0.1 to 0.3 mm².

Friedman test with Tukey’s post-hoc tests was used (P<0.05). All statistical computations were performed with a statistical software (SigmaStat 3.5, Systat Software Inc., Point Richmond, Ca, USA). The level of significance was set at p<0.05.

Results

The midpalatal suture was opened in all subjects. The circle area showed a significant increase from T0 to T1 (+165.7 mm²,) as a consequence of the opening of the midpalatal suture after RME. A significant increase from T0 to T2 (+195.5 mm²) and lack of statistically significant differences from T1 to T2 (+29.8 mm²), was observed (Table 1).

Discussion

The purpose of this study was to analyse the treatment and post-retention effects of RME on the palatal area on axial CT scans. Similar measurements have been attempted in previous studies but research was limited to using 2D X-ray or casts model for data acquisition [Haas, 1961; Starnbach et al., 1966; Wertz, 1970]. The method used in the present study was previously described in literature to evaluate the anterior part of the glenoid in anterior glenohumeral instability, based on the typically circular geometry of the inferior glenoid. A three-dimensional (3D)-reconstructed tomography en face images of the glenoid with “subtraction” of the humeral head was used to overlay a perfect circle that was fit to the glenoid. The anterior aspect of the circle was then adjusted to match the true anatomic contour of the anterior glenoid. This adjusted region was used to determine the percentage of the perfect circle occupied by the glenoid creating an anatomic preoperative description of bone loss [Nofsinger et al., 2010].

Computed Tomography (CT) analysis of RME effects gives better quality and accuracy of the diagnostic parameters measured, and it might soon become the routine analysis for patients undergoing such treatment [Habersack al., 2007; Phatorous et al., 2008]. To our knowledge, the present investigation is the first attempt to use a 3D scanning technique to assess morphologic palatal changes after expansion therapy by using a standardised circle area that is not influenced by tooth position, alveolar and skeletal anatomy.

The total expansion of the palatal area with an RME appliance can be divided in skeletal expansion and alveolar bending. The first one is due to the direct separation of the maxillary halves as a result of the opening of the midpalatal suture, while the alveolar bending is an additional expansion at the buccal alveolar plate [Garret et al., 2008]. At the end of active treatment (T1) the net increase in area was 165.7 mm². This data might suggest that expansion of constricted maxillary arch produces marked increases in the area of the palate and it can be assumed that the marked increase in the palatal area is a result of the midpalatal suture opening in conjunction with alveolar arch tipping. Moreover using a circle area it was possible to demonstrate that RME increased transverse dimension without reducing the arch perimeter. When the circle areas obtained at T0, T1, T2 are superimposed on one point (the external aspect of the palatal cortical plate of the right maxillary first molar), it is pointed out that the orthopedic expansion affected the palatal area in both transverse and sagittal dimensions (Fig.2). This effect was due to the opening of the midpalatal suture that is decreasing from the anterior to the posterior part of the palate.

After a 6-month retention period (T2) the palatal area resulted stable with an additional value of 29.8 mm² during the T1-T2 interval. The appliance was maintained in place as a passive retainer for 6 months to allow complete recovery and reorganisation of the midpalatal suture and to avoid a relapse of skeletal effects in both the oral and nasal cavity.

**TABLE 1** Descriptive statistics and statistical comparisons of extension of circle area at T0, T1, and T2 (Friedman test with Tukey’s post-hoc tests).

<table>
<thead>
<tr>
<th></th>
<th>T0 Mean</th>
<th>T0 SD</th>
<th>T1 Mean</th>
<th>T1 SD</th>
<th>T2 Mean</th>
<th>T2 SD</th>
<th>T0 vs. T1</th>
<th>T1 vs. T2</th>
<th>T0 vs. T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle area (mm²)</td>
<td>525.6</td>
<td>125.2</td>
<td>691.3</td>
<td>97.7</td>
<td>721.1</td>
<td>92.7</td>
<td>165.7 *</td>
<td>29.8 ns</td>
<td>195.5 *</td>
</tr>
</tbody>
</table>

ns: not significant; * p<0.005
Conclusions

› Opening the midpalatal suture by using orthopedic forces allowed to extend the area of the maxilla (T1) increasing the transverse dimension and without reducing the arch perimeter.
› After a 6-months retention period (T2) the palatal area demonstrated a stable increase due to bone deposition along the midpalatal suture in both the anterior and posterior parts of the maxilla.

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