Three-dimensional computerized tomographic orbital volume and aperture width evaluation: a study in patients treated with rapid maxillary expansion

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Objective. The purpose of this study was to assess the influence of rapid maxillary expansion (RME) on orbital volume and aperture width measurements by using freeware software with DICOM data from low-dose-protocol multidetector computerized tomography (MDCT).

Study design. The subjects consisted of 30 patients (12 male, 18 females) treated with a Hyrax Palatal Expander, activated 3 times per day (0.25 mm per turn of the screw) for an average of 18 days. Low-dose MDCT was performed immediately before (T1) and after (T2) treatment. DICOM data was exported into the open-source OsiriX Medical Imaging software (www.osirix-viewer.com), the data reoriented to a standard projection, and then orbital volumetric and maximum aperture measurements performed.

Results. Orbital mean volumes increased significantly from 18.81 ± 1.23 cm³ (T1) to 19.53 ± 1.26 cm³ (T2). Orbital aperture width also increased significantly from 36.02 ± 1.24 mm (T1) to 37.11 ± 1.01 mm (T2).

Conclusions. RME produces small but significant increases in orbital dimensions. However, RME does not produce drastic changes of the normal architecture of the orbital bones and is unlikely to alter the normal anatomy of the face. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;111:503-507)

Rapid maxillary expansion (RME) is one of the most used widely techniques to correct maxillary transverse diameter deficiency and posterior cross-bite. The effects of RME not only involve dental arch width and maxillary vault area but also associated maxillofacial structures.1-4 This includes documented changes to the surrounding frontal process of the maxilla, nasomaxillary suture, frontomaxillary suture, nasofrontal suture, zygomaticomaxillary suture, zygomaticomaxillary suture, and ptterygopalatine suture and an increased nasal cavity width.5-12 In addition, the maxilla articulates with other facial skeleton bones, such as the anterior and middle cranial base.12 Many authors have recognized that the center of resistance, which acts with RME, is mostly represented by the zygomatic complex.12-15 Considerable displacement can be observed at the level of the frontal, zygomatic, and parietal bones, supporting the contention that the zygomaticomaxillary sutures, especially at the level of the zygomatic arch, are influenced by maxillary expansion.16 Similarly, it would seem reasonable to assume that the orbits also may be affected by RME orthopedic treatment. Researchers have reported good correlation between orbital volume increments and the degree of enophthalmos, Grave orbitopathy, and Apert syndrome. An accurate method of orbital volume measurement could therefore assist in the quantification of such changes in treatments, such as the reduction of zygomatic fractures or RME. three-dimensional (3D) reconstructions of data from computerized tomography (CT) or cone-beam CT are excellent diagnostic tools.17,19 However, to ensure precision and accuracy it is necessary to reorient 3D reconstructions along the same axis of symmetry.

The aim of the present study was to 3-dimensionally evaluate orbital volume and aperture width in patients by using high-resolution low-dose multidetector computerized tomography (MDCT) before (T1) and immediately after (T2) RME. The null hypothesis was that there were no significant changes in orbital volume and aperture width between T2 and T1 CT measurements.

MATERIALS AND METHODS

The sample consisted of 30 caucasian subjects (12 male, 18 female) with Angle class I malocclusion, who sought RME treatment at the Department of Orthodontics, Faculty of Dentistry, University of Catania, Catania, Italy. Eight subjects (3 male, 5 female) were included from previous research.16 Inclusion criteria consisted of patients who had bilateral posterior cross-bite, transverse maxillary deficiency, deep palatal vault,
and dental crowding at the start of the treatment. The mean chronologic age of the patients was $9.8 \pm 1.8$ years (range 8-11.4 years). Patients with missing maxillary posterior permanent teeth, metal restorations on maxillary teeth, periodontal disease, previous orthodontic treatment, or craniofacial syndromes were excluded from the study. All procedures were explained to the patients and their parents. An agreement to participate in the study and signed informed consent was obtained from each patient’s parent or guardian as a condition of enrollment. The study was approved by the Ethical Committee of the University of Catania.

**Treatment protocol**

A Hyrax palatal expander was used for each patient. The activation protocol required the screw to be turned 3 times per day (0.25 mm per turn) for an average of 18 days. Expansion was considered to be adequate when the occlusal aspect of the maxillary lingual cusp of the permanent first molar came into contact with the occlusal aspect of the mandibular facial cusp of the permanent first molar.

Multislice CT scans were performed before rapid palatal expansion therapy (time T1) and again at the end of the active expansion phase (time T2) without removing the expander. Multislice CT scans were carried out by a trained radiologist using the same scanner console. A previously described low-dose CT scan protocol was used. Briefly, patients were imaged using a helical MDCT scanner (Lightspeed Ultra; GE Medical Systems, Giles, UK). The scanning parameters were 80 kV, 10 mA, 0.625 mm slice thickness, pitch 1, and gantry tilt 0°. This provides a low-dose protocol compared with standard parameters. Multplanar image reformatting and 3D postprocessing were performed on a workstation (Advantage Windows 4.1; GE Medical Systems). Subjects were scanned in the supine position, with chin and shoulder rests, with the head positioned such that Camper’s plane was perpendicular to the ground.

Patient data were reconstructed with a 0.5 mm slice thickness and saved in the Digital Imaging and Communication in Medicine (DICOM) file format. The data were then transferred to a workstation (Mac Pro Quad 2.66 GHz; Apple Corp., Cupertino, CA, USA) and visualized and analyzed using open-source OsiriX medical imaging software (http://www.osirix-viewer.com). To minimize measurement errors, the data orientation was standardized according to 2 reference planes: nasofrontozygomatic plane (NFZ; a frontal plane passing through the 2 frontozygomatic sutures at the inner rim of the orbit and nasion) and Frankfurt horizontal plane as described by Cho.

**Orbital volume and orbital aperture width determination**

Orbital volumes were calculated manually to determine the contours of the orbit through the cursor on the computer using the region of interest (ROI) function in OsiriX (Fig. 1). The posterior limit was established by scoring a line between the medial and lateral walls of the optic foramen within the orbit. The anterior boundary was defined by a line joining the most anterior bone edges of the medial and lateral orbital walls. Volume measurement was calculated by defining the contours of the orbital on a series of slices for each scan and completing the sequence by using the function “Multiple ROI” available in OsiriX (Fig. 2). To determine orbital aperture width, volume-rendering 3D reconstruction was performed by using the appropriate function in OsiriX, and then the line from the
posterior lacrimal crest to the frontozygomatic suture was measured (Fig. 3).26

Statistical analyses

All measurements were performed by the same observer (E.S.), a postgraduate trainer from the Department of Orthodontics, University of Catania, who was considered to have an appropriate level of knowledge and skill in use of the software. The operator was blinded to the patient being measured.

Method error has been calculated using Dahlberg’s equation for repeating measurements.27 Descriptive statistics, including the means, standard deviations, and standard errors, were calculated separately for each period (T1 and T2). A Shapiro-Wilk test was performed to test normality. Orbital volume measurements had a gaussian distribution, and therefore a paired t test with \( \alpha = .05 \) was performed to test differences in mean orbital volumes between T2 and T1. Orbital aperture width measurements were not normally distributed and so data were compared using a Wilcoxon signed rank test with a probability level of .05 considered to be statistically significant. A post hoc power analysis (1 – \( \beta = 0.80 \)) to t test and Wilcoxon signed rank test was conducted. Statistical computation was performed by using Prism 4.0 for Macintosh (GraphPad Software, La Jolla, CA, USA).

RESULTS

Comparisons of orbital volumes and orbital aperture width before (T1) and after (T2) RME are shown in

Fig. 2. Representative segmented volumetric reconstruction rendering of orbital volume obtained from compilation of single axial slices with the appropriate function in OsiriX.

Fig. 3. Cropped volumetric reconstruction of the left orbit demonstrating maximal orbital aperture width measured as a line from the posterior lacrimal crest to the frontozygomatic suture.

Tables I and II. The quantity of orbital volume and aperture width increase on the right and left sides were not statistically different (\( P > .05 \)), so right and left orbital volume and aperture measurements were combined to compare differences between T2 and T1. Ac-
According to the Shapiro-Wilk test, orbital volume measurements (both T1 and T2) were normally distributed, whereas those of orbital aperture were not. Before treatment with RME (T1) the orbital volume mean was 18.81 ± 1.23 mL (minimum 16.00 mL, maximum 21.5 mL). At the end of the expansion (T2), volumes increased significantly to 19.53 ± 1.26 mL (minimum 16.60 mL, maximum 22.10 mL). The data had high power and Pearson correlation coefficient and a similar coefficient of variation at T1 and T2 (Table I).

Mean orbital aperture width at T1 was 36.02 ± 1.24 mm (minimum 33.40 mm, maximum 39.10 mm), which was significantly different after RME at T2 (mean 37.11 ± 1.01 mm, minimum 35.10 mm, maximum 39.90 mm) The data had high power and Spearman approximation (rs) and a similar coefficient of variation at T1 and T2 (Table II).

**DISCUSSION**

Rapid maxillary expansion is a widespread treatment choice for several conditions which may affect growing patients and lead to maxillary transverse diameter deficiency and posterior cross-bite. These can be induced by obstruction of the upper airways (caused by hypertrophy of adenoid tissues or nasal allergies), finger/thumb sucking or certain swallowing habits. Therefore, it is necessary to know exactly how RME therapy may alter other components of the craniofacial skeleton.

The results of some authors have supported the hypothesis that various adjacent structures are affected via craniofacial sutures with orthopedic devices during RME. Therefore, the orbits could be affected by changes induced by the action of RME on craniofacial sutures.

Quantitative determination of the orbital volume provides valuable data for various disease states diagnosis (Grave orbitopathy, exophthalmos), during surgery planning (pre- and postoperative management of maxillofacial trauma), and in the field of craniofacial prosthetics. Computerized tomography provides 3D data of facial anatomy, facilitating detailed evaluation of these structures. However, because patient position is critical in serial volumetric analyses, it is necessary to reorient CT data. The present investigation demonstrates the use of a free software, OsiriX, to meet this criterion.

MDCT dose-reduction protocols involve appropriate selection of tube amperage (mA), tube voltage (kV), pitch, and gantry tilt. Although reduction in exposure generally implies lower image quality, our investigation supports the results of Sur et al., who suggest that such modifications do not lead to a degradation in image fidelity that affects measurement of the maxillofacial structures.

The results of the present study, comparing orbital measurements before and after RME, indicate small but statistical increases in both volumetric and aperture width and support the theory that these increases occur via suture expansion. However, RME does not appear to produce drastic changes of the normal architecture of the orbital bones and is unlikely to alter the normal anatomy of the face.

**Table I.** Comparison of orbital volumes (n = 30) before (T1) and after (T2) rapid maxillary expansion

<table>
<thead>
<tr>
<th>Time</th>
<th>Orbital volume (mL)</th>
<th>Shapiro-Wilk P value</th>
<th>95% CI</th>
<th>Paired t test</th>
<th>Power 1 – β</th>
<th>Correlation coefficient (r)</th>
<th>Coefficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>18.81 ± 1.23</td>
<td>.37*</td>
<td>18.35</td>
<td>19.27</td>
<td>.9561</td>
<td>.8440</td>
<td>6.57%</td>
</tr>
<tr>
<td>T2</td>
<td>19.53 ± 1.26</td>
<td>.34*</td>
<td>19.06</td>
<td>20.00</td>
<td></td>
<td></td>
<td>6.46%</td>
</tr>
</tbody>
</table>

CI, Confidence interval; S, statistically significant.
*Data normally distributed.

**Table II.** Comparison of orbital aperture width (n = 30) prior to (T1) and after (T2) rapid maxillary expansion

<table>
<thead>
<tr>
<th>Time</th>
<th>Orbital aperture width (mm)</th>
<th>Shapiro-Wilk P value</th>
<th>Paired t test</th>
<th>Power 1 – β</th>
<th>Spearman approximation (rs)</th>
<th>Coefficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>36.02 ± 1.24</td>
<td>.44*</td>
<td>P&lt;.0001 (S)</td>
<td>.9789</td>
<td>.8942</td>
<td>3.45%</td>
</tr>
<tr>
<td>T2</td>
<td>37.11 ± 1.01</td>
<td>.02</td>
<td></td>
<td></td>
<td></td>
<td>2.75%</td>
</tr>
</tbody>
</table>

S, Statistically significant.
*Data normally distributed.
CONCLUSIONS

In this investigation, RME therapy showed the ability to induce an increase of orbital volume and orbital aperture width. Even though these increases were statistically significant, they were not so considerable as to affect craniofacial anatomy.

Differences between measurements at T1 and at T2 were statistically significant, and the null hypothesis should be rejected.

REFERENCES


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