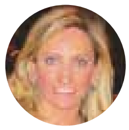
RME: effects on the nasal septum. A CBCT evaluation



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Abstract

Aim Three-dimensional images have been evaluated to study the changes that occur on the maxillary complex and the nasal septum, following rapid maxillary expansion (RME) in growing children.

Methods The records of 39 consecutively treated patients (20 male, 19 female), aged between 6.2 and 12.3 years (mean 8.6 years, S.D. 1.5), presenting a septal deviation of more than 1 mm, were analysed. Each patient was scanned at two distinct periods. The first image (T0) was obtained before treatment and hence represented the patient's baseline condition prior to expansion. The second time point (T1) was set after removal of the expander. The skeletal modifications induced by RME have been evaluated via cephalometric tracings obtained at T0 and at T1. The time lapse between T0 and T1 was 12 months.

Results The nasal septum has been modified in its length more significantly in its lower rather than its upper tract. The width of the piriform aperture increased of 1.58 mm with an increase in the lateral walls and a downward movement of the nasal floor (consequent to an increase in septal length). There was also a reduction of septal deviation. The control group measurements did not vary during the considered period.

Conclusions Evidences of this study suggest that RME procedures can result in: a potentially positive effect on the nasal septum asymmetry during childhood; an increase of the nasal cavity volume due to a downward and forward movement a lateral inclination of the nasal cavity reducing air resistance and improving breathing pattern; an increase of the length of the septum in its lower third improving its possible deviations and growth disturbances; favourable effects on the growth of the entire maxillary complex.

KEYWORD CBCT, Nasal septum, Nasal septum deviation, RME procedures.

Introduction

Nasal breathing is essential for proper growth and development of the craniofacial complex. According to the functional matrix theory, nasal airflow is a continuous stimulus for lowering of the palate and for lateral maxillary growth, indicating a close relationship between nasal breathing and dentofacial morphology [Farronato et a., 2014; Fabiani et al., 2017; Fernandes et al., 2017].

The nasal septum is responsible for regulating airflow through the nose. It gives shape and support to the nasal dorsum and caudal aspect of the nose [Farronato et al., 2012]. It is made up of a vertical lamina that includes two bony parts and a cartilage that generally presents with a slight deflection. [Biagi et al., 2012]. The septal cartilage is a perpendicular plate that extends from the nasal bones anteriorly to the bony septum in the midline posteriorly, then down along the bony floor. It has a quadrangular shape. Its upper half is flanked by two triangular to trapezoidal cartilages, the upper lateral cartilages, which are fused to the dorsal septum in the midline. They are also attached to the bony margin of the piriform aperture laterally by loose ligaments and their inferior ends are free [Biagi et al., 2012]. From its bony parts the upper portion is formed by the perpendicular plate of the ethmoid bone, while the inferior and the posterior part is formed by an independent bone (vomer) that from the margin of the cohanae protrudes into the nares [Sanders et al., 2014] on the frontal bone. The remaining parts of the sphenoidal bone contribute to the formation of the nasal septum [Biagi et al., 2012]. The quadrangular lamina does not reach the tip of the nose, because of the presence of a small membranous part in the anterior part [Biagi et al., 2012]. The primitive nasal cavities, separated from the primitive nasal septum, are in communication with the oral cavity. Their complete separation from the oral cavity occurs around the end of the 8th week with the formation of the posterior palate.

A straight septum enables laminar airflow, allowing the inspired air to be warmed, cleaned, and humidified optimising gas exchange at the alveoli in the lungs. On the contrary, a deviated nasal septum can contribute to various degrees of nasal obstruction and altered nasal respiration [Farronato et al., 2012].

	Mx dx-sx	CVM+ dx-sx	Sept lenght U	Sept lenght L	SNM-X	SNI-X	Width
pre/post	3137	5,83	0,47	0,53	-70%	-85%	1,58
p	0,042	0,015	0,034	0,027	0,037	0,048	0,019
	significant	significant	significant	significant	significant	significant	significant

TABLE 1 Statistical analysis comparing pre-post measurements. All values not preceded by (-) sign indicate increase in the measure. All negative values indicate a decrease. All values are statistically significant. Red and blue lines indicate the measurement's trend.

Nasal obstruction as a consequences of a deviated nasal septum may cause mouth breathing with implication on the tongue and lip positions, mouth posture, downward and backward rotation of the mandible, decreased nasal permeability (resulting from nasal stenosis) and enlargement of nasal turbinate causing a decrease in nasal airway size. Furthermore, the distance between the lateral walls of the nasal cavity and the nasal septum is often decreased [Farronato et al., 2012].

Many authors reported potential favourable effects of RME for the treatment of a combination of nasal imbalances and septal deformity. This is due to the effect of the RME on the increases of the transverse dimensions of the maxilla and nasal cavity due to the separation of the two maxillary halves (by the use of heavy forces) from the midpalatal suture [Timms and Vero, 1981; Timms, 1987; Kiliç et al., 2008].

The procedures to expand the maxilla with the use of the expander were introduced more than a century ago and have been shown to be a reliable and effective method to correct maxillary transverse discrepancies [Woller et al., 2014].

Many studies have attempted to quantify the changes that occur in the maxillary complex, the midpalatal suture, the dentoalveolar structures and the nasal cavity as a result of RME [McNamara and Brudon, 1993; Gray, 1987]. However, the limitations of clinical examinations and two-dimensional radiography inhibit the analysis of what is happening at the sutural levels during orthopedic treatment.

A lateral inclination of the nasal cavity walls that favours a flare of middle nasal means can be observed after RME. Furthermore, during growth, inadequacy of the nasal airway can bring to chronic mouth breathing, causing moderate to severe maxillary constriction.

The introduction of cone beam computed tomography (CBCT) in orthodontics has permitted the examination of the craniofacial complex in living, growing subjects [Woller et al., 2014; Sanders et al., 2014; Maspero et al., 2015].

The purpose of this study is to analyse three-dimensional images to evaluate the changes that occur at the maxillary complex and the nasal septum, following rapid maxillary expansion (RME) in growing children.

Materials and methods

This is a retrospective study approved by the Ethical Commetee of Fondazione IRCCS Cà Granda, Ospedale Maggiore Policlinico of Milan (UOC Chirurgia Maxillo Facciale ed Odontostomatologia, University Department of Biomedical, Surgical and Dental Sciences), approval n. 936 dated 04/23/2014.

CBCT have been performed in patients with the suspect of dental anomalies such as transpositions, cysts, retention and inclusion and to study ear and nose diseases.

The records of 39 consecutively treated patients (20 male, 19 female) aged between 6.2 and 12.3, mean 8.6 (S.D. 1,5) presenting a septal deviation of more than 1 mm were selected based on the following inclusion criteria.

- Growing patients.
- Absence of sistemic diseases.
- Skeletal maxillary transverse discrepancy, requiring the use of a rapid maxillary expansion appliance.
- Complete set of CBCT images including one prior to the cementation of the expander and one taken immediately after the removal of the appliance.

The exclusion criteria were:

- congenital or dental anomalies;
- sistemic diseases;
- previous orthodontic treatment.

Radiographic examination

Each patient was scanned at two different moments. The first image (T0) was obtained before the use of the expander and represented the subject's baseline condition prior to the expansion. The second time point (T1) was taken following the removal of the expander.

The activation protocol of the appliance consisted in one-quarter turn of the transverse screw twice a day until the desired expansion was obtained. Then the appliance was left in place for passive retention.

The skeletal modifications induced by RME have been evaluated through cephalometric tracings obtained at T0, and at T1 (Table 1). A lapse of time of about twelve months passed between T0 and T1. All CBCT were recorded in the same X ray device with the same exposure parameters. Scans were taken using a CBCT scanner. The scanning protocol involved a 4 mm slice thickness, a 16 cm × 22 cm field of view, a 20-second scan time, and a 0.49/0.49/0.5 mm voxel size. The scans were saved in Digital Imaging and Communications in Medicine (DICOM) format, transferred to a personal computer and reconstructed with a 3D image segmentation programme (Mimics 11.1 Materialise, Leuven Belgium). CBCT were taken by the same technician (C.R.), traced by Mimics Software by one operator (L.G.), and verified for landmark location and anatomic contours by a second operator (C.M.). Any disagreements were solved by retracing the landmark or structure to the mutual satisfaction of both of the operators.

The data was statistically analysed through t-test for paired samples ($P<0.05$).

Measurements

The following measurements have been considered:

The nasal septum has been measured in its upper and lower tracts calculating the distance between the points X/ SNM, SNM/SNAC (Table 2). The distance between the medium tract (point SNM) and the lower part of the septum (point SNI) from the axis of symmetry has been evaluated. The width of the piriform hiatus and the distance between

X	Crossing point between the perpendicular plate of the ethmoid and the projection of the floor of the anterior cranial fossa floor
MX	Crossing point of the maxillary tuber and the zygomatic arch - left and right
CVM+	Most prominent point on the sagittal plane of the vestibular-mesial cuspid - upper left and upper right
SNM	Middle nasal septum - middle point on the horizontal plane of the maximal diameter of the medium third of the nasal septum
SNI	Inferior part of the septum-middle point on the horizontal plane of the maximal diameter of the inferior third of the nasal septum
MID	Crossing point between the axis of symmetry and the horizontal straight line that connects the homologous cephalometric points
CON	Point of cephalometric congruence between the inferior condyle of the occipital bone and the contour of the great occipital foramen
Axis of reference	Axis that passes through the right and left CON
Axis of symmetry	Perpendicular of the axis of reference that passes through the highest point of the occipital foramen
NL	Left and right external points at the maximal horizontal diameter of the nasal cavity
SNAC	Anterior cephalometric nasal spine

TABLE 2 Cephalometric definitions.

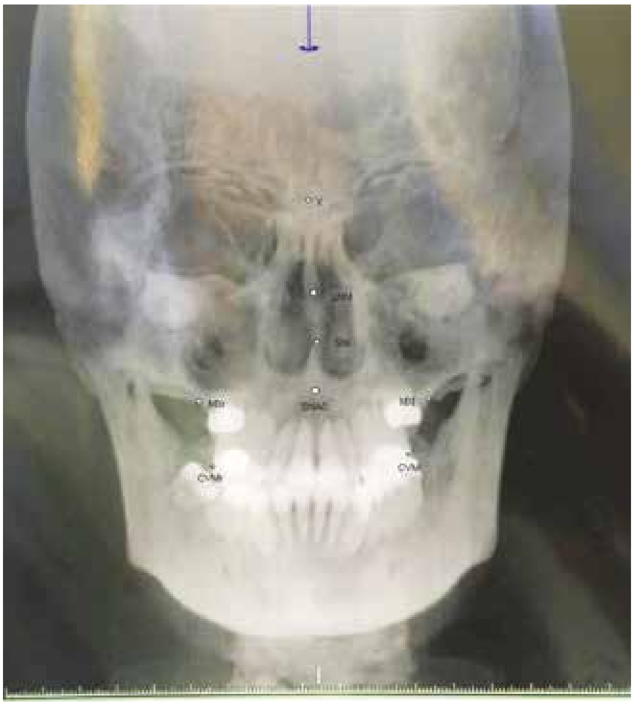

FIG. 1 CBCT image. The nasal septum has been measured in its upper and lower tracts. The distance between the medium tract (point SNM) and the lower part of the septum (point SNI) from the axis of symmetry has been evaluated. The width of the piriform hiatus and the distance between right and left maxillary points (Mx l-r) and upper first molars points (CVM+ l-r) have been measured.

right and left maxillary points (Mx l-r) and upper first molars points (CVM+ l-r) have been measured (Fig. 1).

To exclude intra-operator error, each measurement was repeated by the same operator after a period of seven days.

Results

The Student's t test of the data gathered before (T0) and after therapy (T1) highlighted a few changes.

The distance between right and left Mx points showed a mean increase of 3.37 mm during T0-T1 and this change is statistically significant following Student's t test ($p<0.05$).

The distance between right and left CMV+ points showed a mean increase of 5.83 mm during T0–T1 and this change is statistically significant ($p<0.05$).

The length of the nasal septum increased 0.47 mm in its upper tract and 0.53 mm in the lower tract and this change is statistically significant ($p<0.05$).

The distance of SNM (mid septum) from the axis of symmetry has had an average reduction of 70% while the distance of SNI (inferior tract of the septum) from the axis of symmetry has had average reduction of 85% so septal deviation from sagittal medial line reduced after RME: a reduction of the septum deviation has been found both in its middle and lower tract.

The nasal septum has been modified in its length more significantly in its lower rather than upper tract.

The width of the piriform aperture increased of 1.58 mm with an increase in the lateral walls and a downward movement of the nasal floor (consequent to an increase in septal length). There was also a reduction of septal deviation. The control group measurements did not vary during the considered period.

Discussion

Anatomical adaptation of the tongue and soft palate are common features in subjects with maxillary hypoplasia. RME procedures aiming at correcting maxillary constriction improve the dimensions of the upper airway. An increase in nasal cavity width after RME procedures, particularly at nasal floor adjacent to midpalatal suture, has been observed in literature [Timms and Vero, 1981; Timms, 1987; Kiliç et al., 2008]. The action of the appliance in the palatal vault determines an increase in the intraoral volume to make space for the tongue which can change its posture [Akkaya et al., 1999; Sarver and Johnston, 1989]. In our study an increase of 5.83 mm in the width of the piriform hiatus was found after RME. This result is in agreement with the study of Cross and McDonald who found a mean gain of 2.03 mm in the maximum diameter of the nasal cavity contour measured in postero-anterior radiographs of 17 patients undergoing RME [Cross and McDonald, 2000]. Also Bicakci et al. [2005] measured the width of the nasal cavity and the nasopharyngeal area on postero-anterior and lateral radiographs. The results of this study demonstrated a mean nasal width increase of 3.47 mm after RME therapy. The same results were obtained by Farronato et al. [2012] who obtained a mean gain in the transverse measurement of nasal cavity of 2.81 mm after RME in 20 patients aged between 7 and 11 years.

The effects of RME procedures obtained in our study have been shown and demonstrated by the increase of the distances between MXl/MXr and CVM+/CVM-. The increase in maxillary width was in agreement of the studies of Haas [1961].

Also other authors described the effects of rapid maxillary expansion appliances and they recommend this procedure as the best example of true orthopedic treatment [Haas 1980]. In our study it was also obtained a reduction of the septal deviation both in its middle and lower tracts. The nasal septum has been modified also in its length, more significantly in its lower rather than upper tract. These results are in agreement with previous investigations [Farronato et al., 2012; Gray, 1975; Farronato, 2011]. These favourable effects can be useful during the maxillary growth in young patients because, as described, the septal cartilage acts as a growth center and its deviation determines a distortion of the maxilla with a movement towards the deviated side. This also causes a deviation of the upper midline and a mandibular latero-deviation. In fact, the interdependence of growth in cartilage and bone in craniofacial areas is demonstrated by pathological conditions such as cleft palate and chondroplasia [Farronato et al., 2014; McNamara et al., 2015]. The correction of the nasal septum deviation due to the maxillary expansion seems to have favourable effects in very young patients on all the cranial growth pattern. In fact, the height difference between r-l MX points, r-l CVM+ points, the distance between the upper and lower midlines from the axis of symmetry decreased in all the considered patients between T0 and T1. The analysis of these data underlines that the RME has an influence on all the described variables. Underrating these data means not understanding the etiology of some distortions of the maxilla, of the deviation of upper incisal midline, of the mandibular latero-deviation [Farronato et al., 2011]. Furthermore, a pattern of oral breathing with repercussion on a local and systemic level is likely to be established. Particularly, the passage from oral breathing to the nasal one can be expressed in an alteration of the growth of the nasal capsula and of the dentoskeletal structure, with favourable effects on the craniofacial morphology and alterations of the neuro-muscular system [Lo Giudice et al., 2017; Fabiani et al., 2017]. The sample size of 39 patients is substantially larger than the one used in many other three-dimensional studies. This increased the significance of the statistical analysis. The mid-palatal suture exhibited significant displacement due to RME, with the amount of displacement being greater anteriorly than posteriorly.

The present study showed that there is a positive impact of RME procedures on airway dimensions.

Conclusions

Evidences of this study suggest that RME procedures can result in the following.

1) A potential positive effect on the nasal septum asymmetry during childhood.
2) An increase of the nasal cavity volume due to a downward and forward movement of the nasomaxillary complex.
3) A lateral inclination of the nasal cavity reducing air resistance and improving breathing pattern.
4) An increase of the length of the septum in its lower third improving its possible deviations and growth disturbances.
5) Favourable effects on the growth of the entire maxillary complex.

Conflict of interest

The authors declare that they have no competing interests.

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