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Immediate effects of rapid maxillary expansion on the naso-maxillary facial soft tissue using 3D stereophotogrammetry

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ABSTRACT

Background: Rapid maxillary expansion (RME) is used to expand the narrow maxilla. Dental and skeletal affects have previously been reported but few studies have reported on the overlying soft tissue changes. This study reports on the immediate effects of RME on the naso-maxillary facial soft tissue using 3D stereophotogrammetry.
Methods: Fourteen patients requiring upper arch expansion using RME as part of their full comprehensive orthodontic plan were recruited. Cone beam CT scans and stereophotogrammetry images were taken for each patient; pre-RME activation (T_0) and immediately post-RME expansion (T_1). Based on twenty-three landmarks, 13 linear and 3 angular measurements were made from each of the stereophotogrammetry images. A linear measurement at ANS was taken from each CBCT image. Using a Wilcoxon signed rank test, the pre-RME and post-RME measurements were compared.
Results: The mean separation of the anterior nasal spine was 3.8 mm $\pm$ 1.2 mm. The largest median increase was in nasal base width (1.6 mm), which was statistically significant ($p = 0.001$). Changes in the nasal dorsum height, nasal tip protrusion, philtrum width, and upper lip length were not statistically significant ($p < 0.05$). No significant differences were observed in the nostril linear measurements, expect for columella width ($p = 0.009$). Nasolabial angle decreased but was not statistically significant ($p = 0.276$). The only statically significant angular change was an increase in the nasal tip displacement angle ($p = 0.001$).
Conclusion: Rapid maxillary expansion produces subtle changes in the naso-maxillary soft tissue complex. There is an increase in nasal base width, retraction and flattening of the nasal tip. These changes are small, less than 2 mm and variable between patients.

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Introduction

Rapid maxillary expansion (RME) has been advocated to increase the transverse width of a narrow maxilla. The expansion facilitates posterior crossbite correction, relief of crowding, increase in airway dimensions and has been used in conjunction with facemask therapy to facilitate maxillary advancement.[1–3] The dental and skeletal effects of RME are well documented in the literature. The main skeletal effects produce separation of the mid-palatal suture, more anteriorly then posteriorly, with vertical expansion extending to varying levels. The expansion is often pyramidal in shape with the greatest expansion around the region of the nasal aperture.[4–8] Studies based on two-dimensional lateral cephalograms have shown that the maxilla displaces downwards and forwards to a varying degree following RME treatment.[9] One of the most noticeable dental effects during RME activation is a diastema between the upper central incisors but tipping of the maxillary posterior teeth and alveolar processes laterally have also been reported.[9–12]

Since the maxillary bones contribute significantly to the nasal cavity's anatomical structure, the effects of RME are not just limited to the maxilla but extend to the surrounding nasal structures.[13–16] Conventional tomography has been used to evaluate volume changes in the nasal cavity after RME.[15,17] These authors reported that the internal area and volume increased significantly throughout the nasal cavity. These changes, together with the maxillary advancement, may produce clinically significant changes in the morphology of the naso-maxillary soft tissue.

The potential effects of RME may not be limited to skeletal and dental changes but may be expected to affect the overlying soft tissue; in particular around the nasal soft tissue. Most of the studies carried out to quantify the effect of RME on soft tissue have utilised two-dimensional techniques, including lateral cephalograms[18] and frontal photographic views or by physical direct measurements.[19,20] Measuring three-dimensional changes from a frontal profile photograph will have inherent errors whilst directly measuring changes in nasal width using calipers is clinically difficult with landmark identification and soft tissue distortion being a problem. A more recent study has used cone beam CT to evaluate the changes in the naso-maxillary complex associated with two types of maxillary expanders.[16] However, non-invasive methods of capturing the 3D soft tissue based on stereophotogrammetry are available which have been validated and used for analysis of facial morphology.[21,22]

The aim of the study was to investigate the immediate three-dimensional effects of rapid maxillary expansion on the naso-labial soft tissue using 3D stereophotogrammetry. The underlying hard tissue effects of RME of this group of patients have previously been reported.[23] The null hypothesis was that there is no difference in linear and angular measurements of the naso-labial soft tissue pre- and post-RME.

Materials and methods

Following ethical approval from the West of Scotland Research Ethics Committee (REC reference number: 09/S0709/40), patients were recruited from the Orthodontic Department of the Victoria Hospital, Kirkcaldy, Scotland, U.K. Patients were recruited on their need for upper arch expansion as part of their full comprehensive orthodontic plan; either for unilateral or bilateral posterior crossbite correction and/or relief of crowding. All patients went on to receive full comprehensive orthodontic treatment. Written consent was obtained from each patient and parent or guardian for participation in the study.

The sample size was based on a clinically significant difference of 3 mm in soft tissue change[25] with a standard deviation of 1.13 mm[6] a power of 0.90, and alpha of 0.05. The calculated sample size was 14 subjects.

Clinical protocol

For each patient, a medical and dental history, intraoral and extraoral photographs and dental casts were taken prior to placement of the appliance. No additional plain film radiographs were taken.

Following upper and lower alginate impressions, a cast cap fixed split acrylic design RME appliance with a Hyrax screw (Forestadent, Germany) was constructed. This was cemented in situ with glass ionomer cement (AquaCem®, Dentsply, Germany) by a single experienced Orthodontic Consultant (JMcD).

Data collection

For all scans, subjects were seated with their Frankfort plane parallel to the floor by a single experienced Consultant Orthodontist (BK). An initial pre-treatment, prior to activation (T_0), CBCT scan was taken (i-CAT, Imaging Sciences International, Hatfield, Pa). The scan was performed at 120 kV, 18.45 mAS, for 20 s with a 0.4 mm voxel resolution with a field of view from the supra-orbital ridge to the upper occlusal plane. The image files from the CBCT images were stored in DICOM format (Digital Imaging and Communications in Medicine) and a 3D rendered model built using Maxilim (MEDICIM, Mechelen, Belgium) based on the default threshold values. The methodology of data capture and virtual 3D model visualisation has previously been described in detail.[23]

Immediately following the CBCT scan, a 3D stereophotogrammetry image was taken using a Di3D system (Di3D, Dimensional Imaging, Hilington Park, Glasgow, UK). Prior to image capture the system was calibrated according to the manufacturer's instructions. For all captures, subjects were seated directly in front of the camera system, after removal of any spectacles and jewelry. Each subject was captured in natural head position and rest position.

The parent was instructed to activate the appliance a quarter turn (0.25 mm) twice a day. The patients were reviewed regularly and expansion was stopped when the palatal cusp of the upper molars was touching the buccal cusp of the lower molars.[23] At this point a second CBCT scan and 3D stereophotogrammetry image was taken (T_1) using the same protocol as T_0.

Twenty-three landmarks (9 bilateral and 5 individual) were used (Table 1 and Fig. 1) to measure 13 linear and 3 angular