Effects of rapid maxillary expansion on Holdaway soft tissue measurements

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SUMMARY The objective of the present study was to evaluate short-term soft tissue changes caused by rapid maxillary expansion (RME) in 18 subjects (15 females and 3 males) (mean age 13 years 6 months) with a bilateral posterior crossbite. Lateral cephalograms of the patients were obtained at three different time points: before RME (T1), after maxillary expansion (mean = 0.82 month) (T2), and after retention (mean = 5.95 months) (T3). Holdaway soft tissue measurements were used for the evaluation of soft tissue changes. Data were analysed statistically by means of paired *t*-tests.

The facial soft tissue angle decreased (P < 0.05), and H angle and skeletal profile convexity increased significantly (P < 0.001) at T2. During T3, the increase in the facial soft tissue angle and the decrease in H angle were minimal and not significant, while skeletal profile convexity significantly decreased (P < 0.001). The results of this study indicate that RME may affect Holdaway soft tissue measurements.

Introduction

Rapid maxillary expansion (RME) occupies a unique niche in dentofacial therapy (Timms, 1981). The concept of separating the maxilla by orthopaedic forces dates back almost 150 years. RME was introduced by Angell (1860) and reintroduced and popularized during the 1960s by Haas (1961, 1965). This procedure increases the transverse dimensions of the maxilla by separating the two maxillary halves from the midpalatal suture in a short period. RME has been routinely used to treat transverse maxillary deficiency, posterior crossbites, crowding, and nasal stenosis (Haas, 1965; Wertz, 1970; Hershey *et al.*, 1976; Bishara and Staley, 1987).

Since the maxilla is the second largest facial bone and articulates with nine cranial and facial bones (Timms, 1981), rapid separation of the maxillary halves is likely to result in some changes in the circummaxillary region. A substantial body of knowledge exists concerning the treatment effects produced by RME. Although a large number of articles have been published concerning the skeletal and dental changes with RME (Wertz, 1970; Wertz and Dreskin, 1977; Linder-Aronson and Lindgren, 1979; Memikoglu and Iseri, 1999; Cameron *et al.*, 2002), structural and histological changes in sutures (Debbane, 1958; Haas, 1961; Cleal *et al.*, 1965; Melsen, 1972), alterations in breathing pattern (Wertz, 1968; Hershey *et al.*, 1976; Warren *et al.*, 2008), few have addressed the effects of this procedure on the facial soft tissues.

Karaman *et al.* (2002) evaluated soft tissue changes induced by RME and found that nose tip and soft tissue point A followed the anterior movements of the maxilla and maxillary incisors. Tindlund and Rygh (1993), in an investigation of the soft tissue profile in cleft lip and palate patients during maxillary expansion with a quadhelix, found no significant changes. Ngan *et al.* (1996) evaluated soft tissue and dentoskeletal profile changes associated with maxillary expansion and protraction headgear treatment and found that forward movement of the maxilla was accompanied by a corresponding change in soft tissue profile at a ratio of 50–79 per cent.

Orthodontists have aimed to achieve facial harmony in their patients along with excellent occlusion since Jonn Hunter (Palmer, 1835) declared that one of the prime objectives of orthodontic treatment was to improve the appearance. Angle (1907) suggested that if the teeth were placed in optimal occlusion, it would also result in good facial harmony. A number of researchers have emphasized the major importance of the soft tissues (Burstone, 1958; Subtelny, 1961; Merrifield, 1966; Ricketts, 1968; Holdaway, 1983, 1984).

Holdaway (1983) stated that 'The soft tissue profile plays an important part in our orthodontic considerations. Usually, as we correct malocclusions, we bring about changes in appearance that are pleasing to all concerned. However, most orthodontists who have practiced for even a few years have had the unpleasant experience of finding that some patients' faces looked better before the orthodontic corrections were made'.

Although RME is a common treatment modality in orthodontics, the effects of this procedure on the facial soft tissues have been almost totally neglected. The aim of the present investigation was to evaluate the short-term soft tissue changes as it is not possible to study pure long-term effects of RME on soft tissue facial profile.

Materials and methods

The material of this study consisted of the lateral cephalometric radiographs of 18 patients (15 females and 3

males) who underwent RME at the Department of Orthodontics, Faculty of Dentistry, Ataturk University, Erzurum, Turkey. The subjects had a maxillary width deficiency and a posterior crossbite. Their mean age was 13.50 ± 1.07 years. Informed consent was obtained from each subject prior to the procedure. Lateral cephalograms were obtained at three different time points: before RME (T1), the end of maxillary expansion (T2) (mean = 0.82 ± 0.14 month), and at the end of the retention period (T3) (mean = 5.95 ± 0.35 months).

Rigid acrylic bonded appliances (Memikoglu and Iseri, 1997) were used in all patients. The subjects and/or their parents were told to activate the screw twice a day: one quarter turn in the morning and the other in the evening. The widening procedure was continued until the crossbites were eliminated and 3 mm over-expansion was achieved. The amount of expansion was determined by the increment in maxillary inter-molar distance.

The radiographs were taken by a single operator using standard procedures. During exposure, special attention was given to ensure that the lips were in the rest position. The radiographs were scanned (Epson Expression 1860 Pro, Seiko Epson Corp., Nagona-ken, Japan) under 100 per cent magnification and digitized by one author (NK) using Quick Ceph 2000 (Quick Ceph Systems, San Diego, California, USA).

Holdaway soft tissue measurements were utilized for the evaluation of soft tissue changes. Ten linear and two angular measurements were carried out on each radiographic image. The landmarks were located and the measurements executed according to the definitions provided by Holdaway (1983) (Fig 1).

Statistical analysis

In order to determine the measurement error, 20 films were randomly selected from either the T1, T2, and T3 cephalograms, and their scanning, digitizing, and measurements were repeated two weeks after the first procedure by the same examiner. The first and second measurements of the 20 radiograms were compared (Houston, 1983); no error associated with the radiographic tracings and measurements was found.

A paired *t*-test was used to determine the changes in the measurements between the observation periods. All statistical analyses were performed using the Statistical Package for Social Sciences (Windows 98, version 10.0, SPSS Inc., Chicago, Illinois, USA).

Results

The mean maxillary expansion at T2 was 7.31 ± 1.45 mm and at T3 7.48 ± 1.54 mm. As can be seen from Table 1, soft tissue facial angle decreased (P < 0.05), and H angle and skeletal profile convexity significantly increased



Figure 1 Holdaway soft tissue measurements. A, soft tissue facial angle; B, nose prominence; C, superior sulcus depth; D, soft tissue subnasale to H line; E, skeletal profile convexity; F, basic upper lip thickness; G, upper lip thickness; H, H angle; I, lower lip to H line; J, inferior sulcus to H line; K, soft tissue chin thickness; F–G, upper lip strain measurement.

(P < 0.001) after RME. During T3, H angle decreased and soft tissue facial angle increased but not significantly, while skeletal profile convexity significantly decreased (P < 0.001). Although some recovery in skeletal profile convexity and H angle occurred during T3, the increases in these angles were statistically significant for the total period (P < 0.05).

Discussion

In the present study, the long-term effects of RME on the soft tissue facial profile could not be studied because following the retention period of RME, the use of functional and/or fixed orthodontic treatment procedures were required. This necessity prevents the investigation of the long-term changes induced by RME. No control group was used since the total observation period of this study was 6.76 ± 0.35 months. It is believed that growth increments in the soft tissue profile in such a short period are at an unimportant level (Quintão *et al.*, 2006).

Burstone (1958) claimed that in man, the lower face, besides its functions (digestion, speech and respiration), influences the social acceptance and psychological wellbeing of the individual. According to that author, appearance is one of the primary functions of the face.

Parameters	Pre-expansion (T1)		Post-expansion (T2)		Post-retention (T3)		Comparison of the means		
	Mean	SD	Mean	SD	Mean	SD	T1-T2	T1–T3	T2–T3
Soft tissue facial angle (°)	90.63	3.39	89.48	3.60	89.73	2.41	*		
Nose prominence (mm)	17.29	2.81	17.41	2.87	17.52	2.91			
Superior sulcus depth (mm)	2.01	0.80	2.18	1.08	2.21	1.10			
Soft tissue subnasale to H line (mm)	3.94	1.70	4.06	1.94	4.17	2.11			
Skeletal profile convexity (mm)	1.64	2.87	3.24	2.92	2.30	3.08	***	*	***
Basic upper lip thickness (mm)	15.73	2.45	15.42	2.42	15.58	2.52			
Upper lip thickness (mm)	13.51	1.78	13.29	1.92	13.62	1.72			
H angle (°)	7.53	5.24	9.27	4.53	8.99	4.09	***	*	
Lower lip to H line (mm)	0.57	1.13	0.96	1.09	0.80	1.26			
Inferior sulcus to H line (mm)	4.07	1.13	4.29	1.32	4.25	1.39			
Soft tissue chin thickness (mm)	13.97	1.88	14.01	1.89	14.02	1.83			
Upper lip strain measurement (mm)	2.24	1.21	1.94	1.50	2.09	1.26			

Table 1	Means and standard dev	viations (SD) of the	parameters of the	patients and the com	parative results of a	paired t-test.
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P* < 0.05; **P* < 0.001.

The improvement of facial aesthetics has rapidly become one of the desirable objectives of orthodontic treatment. As orthodontic diagnosis and treatment planning have become more sophisticated and scientific, clinicians should be aware of possible changes in the hard and soft tissues in producing a well-proportioned, balanced, and harmonious soft tissue facial profile at the end of orthodontic treatment (Merrifield, 1966; Ricketts, 1968; Holdaway, 1983, 1984).

Sarver *et al.* (2003) claimed that the soft tissues, not the skeletal proportions, should be the goal of orthodontic treatment. In their opinion, clinicians must establish treatment plans for the dentition and facial skeleton by 'reverse engineering' deducing what would have to be done to the hard tissues in order to achieve the desired soft tissue outcomes.

The relationships between nose, lips, and chin can be altered by both growth and orthodontic treatment (Nanda *et al.*, 1990). Lip thickness increases during childhood and adolescence, reaches a maximum at the conclusion of the adolescent growth spurt, and then decreases in the late teens (Bailey *et al.*, 2003). Likewise, the soft tissue thickness of the chin demonstrates increments between 12 and 17 years of age (Bailey *et al.*, 2003).

There is a strong, but complex, relationship between hard and soft tissue changes (Ksai, 1998). Several studies have addressed the effects of different orthodontic and orthopaedic treatment modalities on facial soft tissues (Bravo, 1994; Basciftci *et al.*, 2004; Quintão *et al.*, 2006). Unfortunately, there is a limited database of evidence of the soft tissue changes subsequent to RME (Tindlund and Rygh, 1993; Ngan *et al.*, 1996; Karaman *et al.*, 2002). Karaman *et al.* (2002) showed that while the maxilla and maxillary incisors moved anteriorly because of RME, the nose tip and soft tissue point A followed the hard tissue movements. However, Tindlund and Rygh (1993) found no significant change in the soft tissue profile during the

maxillary expansion period. This finding is not coincident with the results of the present study. This difference may be explained by the fact that those authors carried out maxillary expansion in cleft lip and palate patients using a quadhelix appliance. Ngan *et al.* (1996) evaluated the combined effects of maxillary expansion and protraction, and thus it is impossible to determine the pure effects of RME from their results.

In the present study, no statistically significant change in soft tissue chin and lip thickness was observed during the observation period. H angle increased after RME (P <0.001), while an insignificant decrease was observed in this angle during T3. The H angle shows the prominence of upper lip in relation to the overall soft tissue profile (Holdaway, 1983). The increase in this angle may result from forward movement of the upper lip, clockwise rotation of the mandible, or both. Downward and backward movement of the mandible after RME may explain the finding in the present study of the increase in H angle and the decrease in soft tissue facial angle since one of the direct consequences of RME is downward and backward mandibular rotation (Wertz, 1970; Haas, 1980). It has been shown that the maxilla moves forward as a result of RME (Haas, 1965, 1980; Wertz, 1970; Wertz and Dreskin 1977). Karaman et al. (2002) and Kilic (2005) found that the upper lip moved forward after RME as a consequence of anterior movement of the maxilla. The increase in H angle observed may also have resulted from forward movement of the upper lip.

As expected, forward movement of the maxilla together with the clockwise rotation of the mandible resulted in an increase in skeletal profile convexity. This finding is in agreement with previous research (Haas, 1965; Wertz, 1970; Karaman *et al.*, 2002).

In the present study, there was no effect of RME on nose prominence. This seems somewhat debatable since Karaman et al. (2002) noted an increase in the distance between pronasale and the vertical reference plane after RME. On the other hand, Bailey et al. (2003) demonstrated that RME could lead to undesirable changes in the nose. They claimed that in a 5-year-old girl, after 10 days of RME, the nasal contours were changed and a dorsal hump developed. This may be related to the backward movement of the nasal tip. Some studies have reported widening of the nasal cavity up to 4.5 mm after RME (Haas, 1961) and that the change in nose width was maintained after 1 year of retention (Berger et al., 1999). Guyuron (1988) stated that 'since the nasal frame almost completely controls the nasal form, it is clear that by changing the skeleton one can control the shape of the nose'. It is reasonable to think that by widening the nasal cavity, the soft tissues, especially the tip, of the nose may become flattened and this effect may cause dorsal hump development.

In the present study, there was no difference between initial and final nose prominence measurements. It has been shown that the nose grows in a forward direction to a proportionately greater degree than the other soft tissues of the facial profile (Subtelny, 1961) and that the nose tip usually increases on average by approximately 1 mm/year anterior to the facial plane (Subtelny, 1961, Nanda *et al.*, 1990). Therefore, growth and maxillary forward movement may have compensated for the flattening effect of RME procedure on the nose found in the present study. Nevertheless this phenomenon needs further investigation.

Conclusions

- 1. The soft tissue facial angle decreases and the H angle and profile convexity increase after RME.
- 2. Soft tissue facial angle and H angle showed insignificant changes during the retention period.
- Although some recovery took place during retention, the increases in skeletal profile convexity and H angle were statistically significant for the total period.
- 4. RME procedures may affect soft tissue measurements, and thus these effects should be taken into consideration when utilizing RME

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